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Full Length Research Paper

Study of sand concrete from Sénégal

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Abstract:
Sand concrete is often used in aggregate-poor countries. Its main component is sand. It is a type of concrete without any fine gravel consisting mostly of sand, able to provide strength as satisfactory as those of classical concrete. As Senegal is a country abounding in sand, it is interesting to carry out a physical characterization of the different kinds of sand in order to see their influence on this sand concrete and to assess the performances of this concrete in terms of use and strength.
Types of sand from various quarries in Senegal were studied: Dakar (Kayar) Mbour (Ndiaganiao), Thies (Thienaba). Crushed basalt from Thies (Ngoundiane) was also tested. Different physical characteristics of these types of sand were determined in order to see their effect on the overall sand behavior.
The results show that the crushed sand with a sand equivalent of 80.29 and a modulus of fineness of 3.176 gives the sand concrete a better compressive strength (28.65 MPa) compared to the other sands.
Keyword: sand, sand concrete, characterization, strength.

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1. Introduction
Concrete has for a long time been an important and very useful resource for man who uses it in all fields of building and civil engineering. This material is appreciated and very much in demand thanks to the advantages it provides in terms of resistance, achievement and use. Concrete is a mixture of cement, aggregates, sand, water and, sometimes, other additions – A great deal of research has been carried out on this material [1], [2], [3], [4], [5], [6]. The results of this research have shown that the two essential properties of concrete are workability and strength. These two performance criteria depend on the water / cement ratio of the paste (phase containing cement and water) and therefore on the porosity of the paste, but also on the compactness of the granular skeleton. Good concrete must have satisfactory compressive strength and a good workability. Each of its components plays an important role and has its share of influence in the good performances sought for in the various types of concrete. These constituents have to be high quality and in optimal quantities in concrete mixture. They have their own characteristics which make it possible to know their behavior and effect in the types of concrete.
Sand is an aggregate consisting of fine elements from rocks. It is considered as an aggregate in concrete. It is a widespread material. Sand comes from different places (on land, in water), there are several types of it and it can be found in quasi-inexhaustible amounts in several countries.
In Senegal, sand exists in large quantities in the sea, watercourses, sand dunes etc. Sand, in the country, is mainly produced from loose rocks and massive rocks. Several sand quarries can be found where the material is extracted from before being used in concrete. But this mixture cannot be made up at random for this could be dangerous for man. The quantities needed have therefore to be determined and all its component characteristics to be studied.
Sand has its different characteristics which exercise their influences on concrete good behavior. It is a set of grains with various possible sizes, liable to absorb water. Dirty sand, for example, can surely present drawbacks for concrete. To study sand properly, there are standards about the different types of building sand upon which one has to be based. Hence, the interest in carrying out a study on the concrete sand from Senegal, determining the characteristics of some types of sand and seeing their effect on concrete.
Very large quantities of sand are found in Senegal at low cost. The fine gravel cost, as well as its production, is sometimes high, when it represents an element which is as important as sand in concrete. There is a type of

concrete without any fine gravel called sand concrete. This concrete only consists of cement, sand, water and, sometimes, other additions. This concrete achieves strengths as satisfactory as those of conventional concrete. It all the same requires adding some additive that improves its strength and fines that better the granular body of this concrete.
It would therefore be interesting to study some sand types of the country with this sand concrete. This would make it possible not only to characterize the types sand but also assess the sand concrete strength.
To achieve these objectives, four sand samples were studied : Kayar sand (Dakar), Thienaba sand (Thies), Ndiaganiao sand (Mbour) and Ngoudiane crushed basalt (Thies).
In this paper, the materials and the characterization methods are first presented; then a sand concrete characterization is performed and finally the results obtained are interpreted.

2. Materials and characterization methods

The materials studied are presented as well as the equipment used to achieve experimental tests.

2.1. Materials

For sand concrete, the following materials are used: 42.5 R cement from Dangote, sand from Dakar, Thiès, Mbour and Tambacounda, tap water and a Sikament mf 90 adjuvant which is a super plasticizer.

2.2. Material characterization methods

In this paragraph, the various methods used for the experimental characterization of materials are presented.

2.2.1. Sand characterization methods

2.2.1.1. Sand characterization methods

The coefficient of absorption represents the water absorption capacity of an aggregate. This parameter was determined as follows: The sand was immersed in water for some time, then dried gradually until the free flow state was reached. A weighing machine and a tapered mold were used to determine the coefficient of absorption. Some quantity of sand was immersed in water for 24 hours. The sample was spread out on a dish and displayed in the open air to allow the sand to dry. The sand was tactfully stirred so as to obtain uniform drying. The operation was repeated until the sand grains were free from capillary forces (Figures 1 and 2), meaning there was no longer any water binding the sand grains.

Figure 1: sand with grains not yet free from capillary forces.

Figure 2: Sand with grains free from capillary forces.

When the sand subsided after removing from mould, that is there was no longer water among the grains, a mass called M_a was weighed. The mass was put in a drying oven at a temperature of 200°C for 24 hours and called M_s when getting out of the drying oven. The coefficient of absorption was achieved with the help of the following equation:

$$Abs = \frac{M_a - M_s}{M_s} \quad \text{[Eq. 1]}$$

2.2.1.2. Granulometric analysis

The granulometric analysis is a test allowing a size distribution of the grains constituting an aggregate to be established. Thanks to this analysis, it is possible to obtain a sand fineness module enabling the fine element proportion of a type of sand to be determined. To perform the tests, the equipment used was as follows: a series of standardized sifters, an electric sifter (Figure 3) and a weighing machine.

Figure 3: Electric sifter.

The test consists in separating a material into several granular classes by using a series of sifter displayed by decreasing diameters from high to low. The material was poured into the first sifter. After oscillations of the series of sifters, the aggregate remainder (oversize) was weighed for each sifter. The oversize and screened material percentages were then determined. The fineness module was computed by adding the following sifter cumulated oversize percentages: 0,16; 0,315; 0,63; 1,25; 2,5; 5; 10; 20; 40; 80. It is provided by the following formula:

$$M_f = \frac{R0{,}16 + R0{,}315 + R0{,}63 + R1{,}25 + R2{,}5 + R5 + R10 + R20 + R40 + R80}{100}$$

[Eq. 2]

2.2.1.3. Absolute volume masses determination

The absolute volume mass is the material mass per volume unit without considering the vacuums present in the grains. The sand absolute volume masses were determined by means of the pycnometer method. To carry out the tests a pynometer and a weighing machine (Figure 4) were used.

Figure 4: Mass of the pycnometer and water.

Figure 5: Mass of the pycnometer, water and crushed sand.

The pycnometer was filled with water up to the landmark line, then all the set was weighed and the mass was called M_1. A mass M equal to 300 g was introduced into the device before the pycnometer was half filled with water. The underpart of the pycnometer was strummed to clear, then it was filled with water up to the landmark line. The actual volume mass of the aggregate was obtained by:

$$\rho = \frac{M \times \rho_{eau}}{M_1 + M - M_2} \quad \text{[Eq. 3]}$$

2.2.1.4. Sands cleanness determination

The sand cleanness was determined by using the sand equivalent test. The test was performed with two samples for the analysis for more accurate results. The test tube was filled with water up to the first gauge line. A 120g mass of sand was poured into each test tube with the help of a funnel. To clear the air out, it was deemed necessary to strum the under part of each test-tube while slanting it. The test-tubes were left to rest for 10 mm. The test-tube was fixed horizontally in an automatic vibrating machine. It was vibrated 90 times in 30 seconds. The test-tube was filled with water while rinsing out its inner part and stirring the sand up to the second gauge line (figure 6). The whole thing was left to rest for 20mn. The height h1 of the flocculate higher level and the height h2 of the clean sand higher level were measured by using a reglet (figure 7). The piston moves down in the test-tube until it rested on the sediment. The sliding sleeve was blocked up on the piston rod. A reading of height h2 of the sediment was carried out at the level of the sleeve higher side.

Figure 6 : Piston sand equivalent.

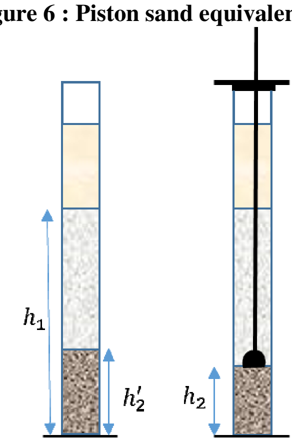

Figure 7: Sand and water level representation.

The visual sand equivalent (VSE) and the piston sand equivalent (SE) were given by the following formulas:

$$VSE = 100 \times \frac{h'2}{h1} \quad \text{[Eq. 4]}$$

$$SE = 100 \times \frac{h2}{h1} \quad \text{[Eq. 5]}$$

The final result is the average of the values obtained with the two test samples for analysis.

2.2.2. Sand concrete characterization methods

The formulation of the concrete is based on the experimental project method of SABLOCRETE [7], [10]. The target resistance is 30 MPa with a theoretical workability at the manometer B of 5.5 s. The adjuvant used is sikament mf 90.

Table 1: Formulation with the sand from Thiès.

	Thiès		
Quantity (kg)		0,7	
ρ (kg/m³)	Cement	Sand	Water
Volume (m³)	545	1116,5	405,4
∑ Volume (m³)	3100	2521	1000
Quantity (kg)	0,176	0,443	0,405
ρ (kg/m³)		1	

The amounts of cement (545g) and of water (381.5g) were fixed by varying the amounts of sand for each type of sand. For each sand type, the mass of water the sand has to absorb in function of its coefficient of absorption was added to the water. The additive (5.45g) was gauged in function of the cement amount: 1% of the cement amount. An E/C=0.7 ratio was used. For example, the formulations of the Thies and Kayar sands are presented in Tables 1 and 2.

Table 2: Formulation with the sand from Kayar.

Kayar			
E/C		0,7	
Material	Cement	Sand	Water
Quantity(kg)	545	1125.5	394.89881
ρ (kg/m^3)	3100	2542	1000
Volume (m^3)	0.176	0.443	0.395
∑ Volume (m^3)		1	

2.2.2.1. Workability of the concrete

The Workability is the ability of the concrete to be easily used to fill formworks and well embed reinforcements. It represents the concrete fluidity before setting. As far as conventional concrete is concerned, workability is measured by means of a subsidence test with the Abrams cone.

For sand concrete, a method different from the one generally used is suggested to measure workability. Fresh concrete workability is determined with the help of a funnel. The minimum diameter measuring the workability is 15 cm and the maximum diameter 55 cm. This method, which was used by the authors for the first time, is not standardized but made it possible to have an idea of the capacity of the different types of concrete to be made use of. After a mixture had been carried out for each type of sand, a funnel was put on the soil and the mixture was poured into the funnel, then, it was lifted. As the concrete was about to subside the subsidence diameter was measured (Figure 8). This diameter will make it possible to differentiate the workability for each mélange.

Figure 8: Measure of the workability of the sand concrete (sand of Thiès).

2.2.2.2. Mechanical resistance determination

The press (Figures 9, 10) used is a test machine of 3000 kN with a numerical acquisition unit (digilab 2000) of reference C0070S manufactured by Controlab. The mechanical resistances were determined by means of compression (Figure 9) and bending tests. The compression tests were made on the 3rd day, 7th day, 14th day and 28th day.

Figure 9 : Compression test.

Figure 10: Bending test.

3. Results and discussion

This paragraph presents the sand characterization and that of the sand concrete.

3.1. Sand characterization

For each type of sand, the coefficient of absorption was determined with equation (1), the fineness modules were computed with equation (2), the volume mass is given by equation (3) and the sand equivalent was obtained by equation (5).

The sand concrete physical characterization results are presented in the following table:

Tableau 3: sand concrete physical characterization results.

Sands	Abs	M_f	ρ	SE
Mbour	0.01005	0.976	2.5	66.83
Thiès	0.02137	1.31	2.521	39.11
Kayar	0.0119	1.235	2.542	81.24
Crushed sand 0/3	0.03626	3.176	2.777	80.29

The crushed sand has the highest coefficient of absorption. As a result, it absorbs most water in the mixture. Mbour sand has the smallest coefficient of absorption. It therefore absorbs the smallest amount of water in the mixture. This could be explained by the fact that the crushed sand does not have a rounded shape compared to the other sands but rather an angular shape which increases its surface causing a water absorption capacity.

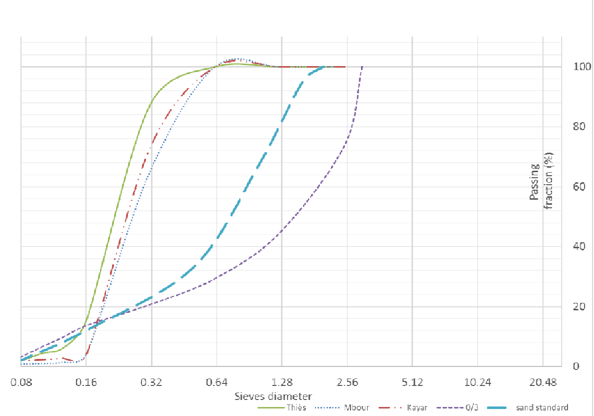

Figure 11: Granulometric curves of the types of sand.

For a better reading of the results, the sands studied were compared with the standardized reference sand. Figure 11 shows that the crushed sand has a spread out granulometry similar to that of standardized sand, the other types of sand have unvarying granulometries. The spreading out causes the crushed sand grains to be better distributed thus giving then good compactness. The fine types of sand then have bad compactness.

In addition, the granular extent (ratio of the largest grain to the smallest diameter) of the crushed sand is 31.25, while the others have a granular extent of 3.94. Indeed, the smaller the porosity of a mixture is the smaller the granular extent [8]. Caquot [9]

] was able to establish experimentally a mathematical relationship between the porosity of a granular stack and the inverse of the granular extent:

$$p = p_0 \sqrt[5]{\frac{d}{D}} \quad \text{[Eq. 6]}$$

In this relation p_0 is an experimental constant.

Table 3 shows that the Mbour sand is the finest sand whereas the crushed sand is the most coarse-grained. There are intervals for fineness modules values, set by the standard XP18-545, allowing types of sand to be classified according to those values:

$1.8 < M_f < 2.2$: fine sand, $2.2 < M_f < 2.8$: preferential sand for concrete, $2.8 < M_f < 3.8$: coarse-grained sand. According to the results obtained, Mbour, Thies and Dakar types of sand are the preferential type for concrete according to the above classification.

The volume masses for the different types of sand are presented on Table 3

The results presented on table 3 show that Mbour sand is slightly clayey, Thies sand is very clayey, Kayar sand and the crushed sand are very clean.

3.2. Sand concrete characterization

3.2.1. Sand type effect on workability

How easy it is to make up concrete depends on its workability. This is measured by its subsidence value. Figure 12 represents the various subsidence values obtained with the various types of sand studied. The crushed sand is seen to have the highest subsidence (39 cm), slightly higher than Kayar sand (36 cm), Thies sand has the smallest subsidence (20 cm). Mbour sand shows a 32 cm subsidence Kayar sand and the crushed sand have sand equivalent values of about 80 % ,Mbour sand has a values of 66.8 % and Thies sand 33.11 % . It follows that sand cleanness plays a significant role in concrete workability. The cleaner the sand, the more workable the concrete. This can also be explained by the fact that the granular extent and the fineness modulus of the crushed sand are larger and therefore the porosity of the granular skeleton is lower, hence the volume of the paste necessary to fill the porosity of the granular skeleton Is low compared to other sands. The excess of the paste will be used to spread the granular skeleton and thus promote the workability.

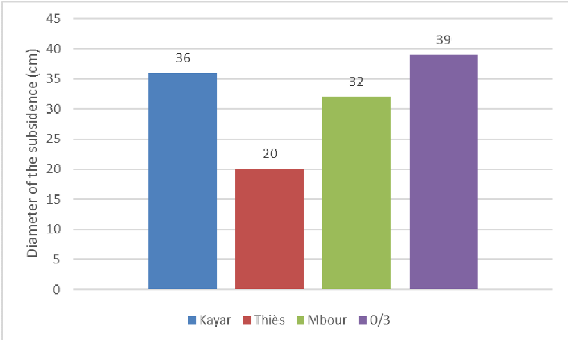

Figure 12: Sand type effect on the workability.

3.2.2. Sand type effect on resistance

The concrete mechanical resistance grows in the course of time and is mainly dependent on its different constituents. The compression (Figure 13) and bending (Figure 15) resistances were determined at 3, 7, 14 and 28 days.

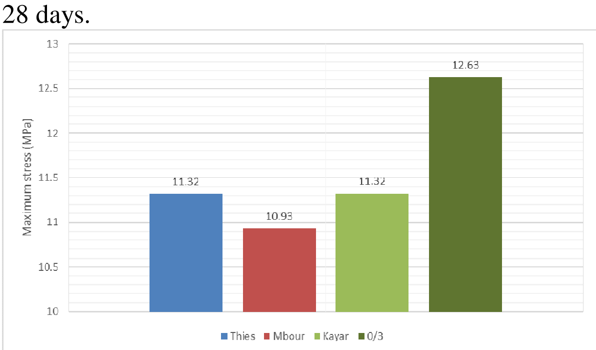

Figure 13-a. Compression resistance at 3 days.

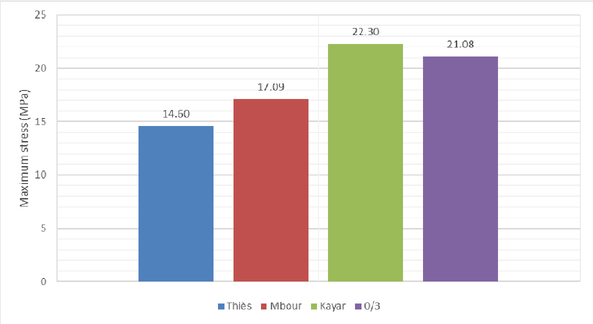

Figure 13-b. Compression resistance at 7 days.

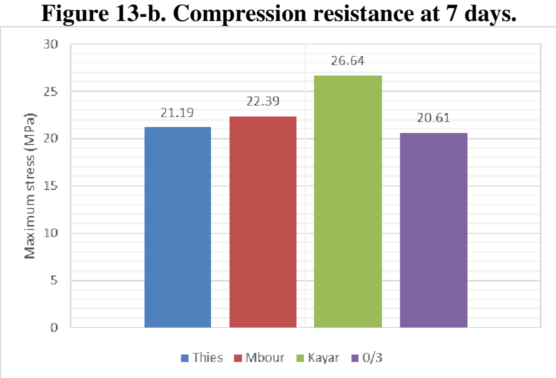

Figure 13-c. Compression resistance at 14 days.

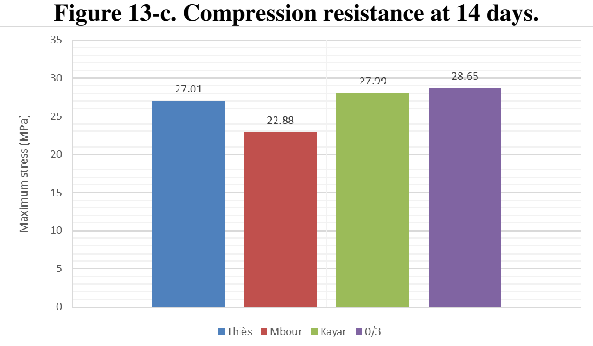

Figure 13-d. Compression resistance at 14 days.

Figure 13-a shows that the concrete with crushed sand (0/3) has the highest resistance and the concrete with the Mbour sand has the lowest resistance (10.09 MPa). The types of concrete with the Thies and Kayar types of sand have equal resistances (11.32 MPa).

Starting from 7 days (Figure 13-b), all the resistances are seen to have increased and it can be noticed particularly that the resistance with the Kayar type of sand goes beyond that with the crushed sand (0/3) and that with the Mbour sand goes beyond that with the Thies sand.

The granulometric analysis of the crushed sand (0/3) has shown that the granulometric curve (Figure 11) of this type of sand has the same trend (spread out) as that of standardized type of sand. This trend shows that these types have a better granularity compared with the fine grained types of sand whose curves present a uniform trend. This granulometry provides the aggregates with better compactness, which increases the concrete strength. The crushed sand equivalent is of 80%, which makes it a very clean type of sand, without clayey particles that may be harmful to concrete.

Nevertheless, at 3 days the Kayar sand gets the advantage over the crushed sand. It presumably follows that the resistance growth with the crushed sand is delayed. As a matter of fact, the crushed sand does not have a rounded shape like the other types of sand but rather an angular shape, which increases its surface area leading to a high water absorption capacity (The coefficient of absorption of the crushed sand = 0.0036). and by absorbing too much water it delays the hydration process of the cement to be hardened.

There are resistances of 14.06 MPa, 17.09 MPa and 22.30 MPa respectively for the Thiès, Mbour and Kayar types of sand and sand equivalents of: 39.118 %, 66.834 %, and 81.244 %, respectively. The Kayar SE in the interval (70>SE>80) of types of sand appropriate for high-quality types of concrete. It results that the higher SE, the higher resistance.

After the test-tubes breakdown on the 14th day (Figure 13-c), it appears above that the concrete the Kayar sand is still the strongest (26.64 MPa). the strengths with the Thiès (21.19 MPa) and Mbour (22.39 MPa) types of sand are higher than that with the crushed sand (20.61 MPa).

The concrete characteristic strength is obtained at the end of 28 days. It can be seen that the strength with the basalt sand 0/3 is the best (28.65 MPa) (Figure 13-d).

This could be explained by the fact that:

• the hydration of the cement with the crushed sand which was delayed in the short term is completed in the long term.

• the porosity of the granular skeleton of the crushed sand is low (spreading granulometry) and that its modulus of fineness is adapted to the concrete, while its resistance lost in the short term because of its high absorption is compensated at 28 days.

But the strength with the Thiès sand goes beyond that of with the Mbour sand. Now, the Mbour sand is cleaner than that of Thiès.

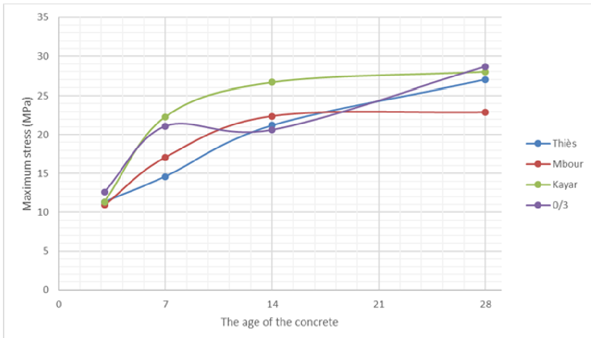

Figure 14: Concrete compression strength evolution in function of the concrete age.

Figure 14 presents the concrete compression strength progress in function of the concrete age. This presumably can be explained by the fact that this sand with its coefficient of absorption of 0.0213 higher than that of Mbour (0.01) disturbs the cement hydration, leading to a short-term strength progress slowness.

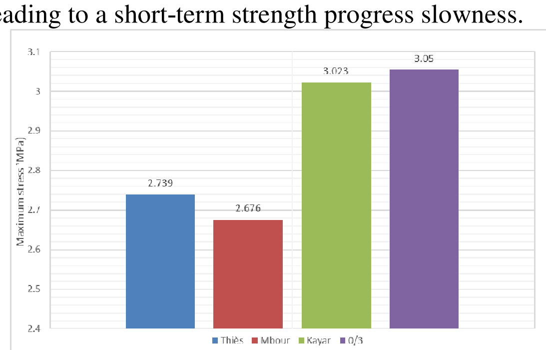

Figure 15-a. Bending resistance at 3 days.

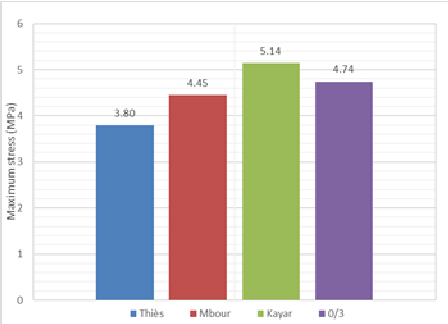

Figure 15-b. Bending resistance at 7 days.

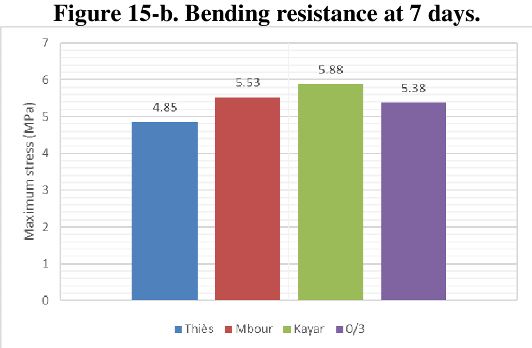

Figure 15-c. Bending resistance at 14 days.

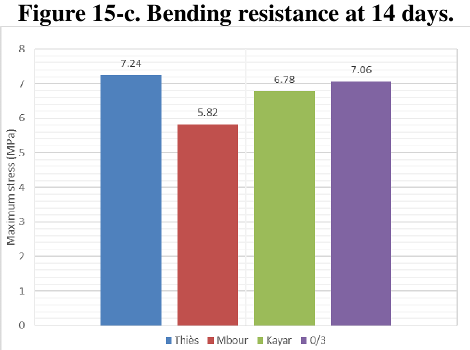

Figure 15-d. Bending resistance at 28 days.

According to figure 15-a, the crushed sand (0/3) appears to have the greatest tensile strength (3.05 MPa). It is slightly higher than that of kayar (3.023 MPa). thethies and Mbour types of sand have strengths of (2.739 MPa) and of (2.676 MPa) respectively.

Starting from the seventh day (Figure 15-b) all the strengths appear to have increased. It can be notice particularly that the strength of the kayar sand is superior to that of the crushed sand and that of this.

Figure 15-c shows that kayar sand is still the highest with 5.88 MPa.

At 28 day, the evolution changes: 7.24 MPa for Thies, 6.78 MPa for Kayar and 5.82 MPa for Mbour (Figure 15-d).

The values obtained in traction by splitting vary a great deal and show that the concrete does not have high tensile strength.

4. Conclusion

The aim of this work was to study various types of sand coming from different quarries of Dakar, Mbour, Thies in Senegal together with some crushed gravel. The coefficient of absorption, the granulometry, the fineness module and the cleanness of these types of sand were determined.

Concrete resists better in compression and its characteristic strength was reached at the end of 28 days. In the results achieved, it appeared that the crushed gravel concrete ((0/3) has the best strength. At 3 days, this same concrete type had the best strength owing to its good granularity but it was established that this sand slows down the concrete strength progress because of the large quantity of water it absorbs delaying the cement hydration. And then the types of concrete with the Kayar, Thies and Mbour sands were obtained which have the best strength. The methylene blue test could be used to determine the amount of clay present in the Thiès and Mbour sands. This will make it possible to decide on their use in construction.

Sand concrete can be used in almost all the same areas as conventional concrete. It actually offers satisfactory enough strength values. The use of this concrete can sometimes be more beneficial and efficient than the use of conventional concrete. In the technical aspect for example, with hard to fill framework or a good setting on reinforcements. In some works, it would be easier to use as it is less heavy and easier to handle.

Moreover, Senegal is a country richer in sand than in grits. More extensive research can be carried out in order to take advantage of these resources in sand and develop sand concrete. It would be interesting to investigate further by studying: porosity, permeability, durability tests, thermal tests.

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