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Contribution to Improving the Performance of Concrete: The Case of the Use of Desert Sand of the Region of Dakar

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Abstract: Although the extraction of sea sand is not the only factor responsible for coastal erosion, it is an important phenomenon in the degradation of the coastal environment. For this reason, local authorities have banned the use of sea sand and also operators in the construction sector (Public Works and Water Resources) should use the desert sand that is the only current alternative. Indeed, the alluvial sand usually has better features than the desert sand, but it is not available in sufficient reserves to the needs of the construction sector. The purpose of this study is to characterize (granularity, cleanliness) some quarries of desert sand used in the Dakar region to verify the extent to which they are used in construction and more specifically in hydraulic concrete composition. Furthermore, a method of mixing improved this desert sand with crushed sand 0/3, from the rock crushing mass, is studied below.

Keywords: Cleanliness, concrete, fineness, sand, strength

INTRODUCTION

In order to improve the quality of concrete used for construction in Senegal, many researches have been done (Tamba *et al*., 2007; Farsi *et al*., 1998, 2000; Gaye *et al*., 2001).

The development of concrete requires a thorough knowledge of the characteristics of its components. These elements consist of aggregates (gravel, pebbles, sand), cement and water. Gravel and pebbles are usually from crushing rocks while the sand from the littoral environment, alluvium or dunes. Rocks Aggregates are one or more of minerals (Hatch *et al*., 1979) formed from molten lava either of cooling, consolidation or alteration of sediment rock materials of already formed under high pressures and temperatures. Indeed, the sand is the element that has in the concrete, according to its qualities, a major influence (Dreux, 1981). According To Abdelhamid *et al*. (2009), a combination based on Desert Sand (DS), Rolled Sand (RS) and Cruched Sand (CS) to Self Compacting Concrete improved (CSC) the compactness of the granular mixture and the intergranular voids decreased volume.

Aggregates constituting a concrete are composed of heavy elements (gravel, pebbles) and fines (sand). The hydrated cement paste and sand form the mortar that role will be to bond with the coarse aggregate to form a solid structure. The strength and stiffness of the mortar will then depend on the type of cement used and also the type of sand. When the sand is thin, it can't form with cement a solid mortar capable of occupying the voids between the large elements. However when the sand is too large, it has the capacity to form a concrete having good mechanical properties but a poor workability.

According to Laquerbe *et al*. (1995), use of desert sand in concrete is possible and can improve slightly the resistance of concrete.

To elaborate an alternative to standardized sand, many researches have been done in quarries sand (Diop *et al*., 2002). Senegal has large quantities of rock materials and sandy formations cover 70% of the country. Sands have minimum of 80% quartz. They find themselves on the coast, inland and often cover most of the Senegalese territory. Reserves of sand available in Senegal are considerable. There is no exact number on them (Diop *et al*., 1999).

The properties of sand discussed in this study mainly on the fineness modulus (measured from the particle size analysis) and cleanliness (measured from the sand equivalent test) have a significant effect on the resistance and workability of concrete.

Mortar prepared from desert sand, beach sand and alluvial offer resistance significantly lower than reference mortar because of their poor graduation and fineness (Diop *et al*., 2002). This character shows significant role of sand in concrete quality.

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Mixture of sands contributes to spread the particle size, increasing the grain size and improve the resistance of mortars (Diop and Esteoule, 1997) (Fig. 1).

The objective of this study is to find ways of improving the desert sand by mixing it with crushed sand to make it usable in concrete composition. Initially, the desert sand from three quarries in the area of Dakar will be studied. The desert sands are the most common detrital formations in the Senegalese-Mauritanian basin. Then, improved sand desert sand with crushed basaltic sand will be studied in the second part of the document.

CHARACTERIZATION OF DESERT SAND FROM THE QUARRY OF TIVAOUANE PEULH AND SO TO KEUR NDIAYE LO AND NIAGUE

Presentation of the quarries: All three quarries are located in the department of Rufisque. Tivaouane Peulh is a small village not far from Keur Massar and its quarry spanned a large area and consists of white sand that comes in a uniform appearance. The quarry of Niague is located between Lac Rose and Niakoul Rap and presents an appearance similar to that of Tivaouane Peulh. On a less subject than the first two, the quarry of

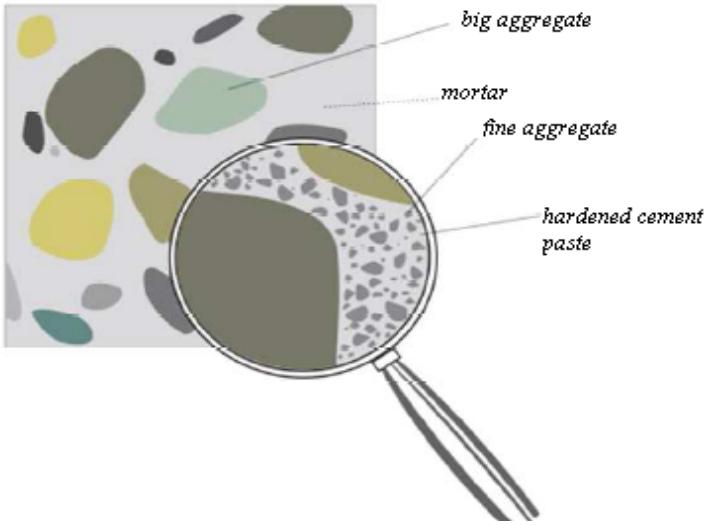

Fig. 1: Components of a hardened concrete (Concrete Group Belgian, 1994)

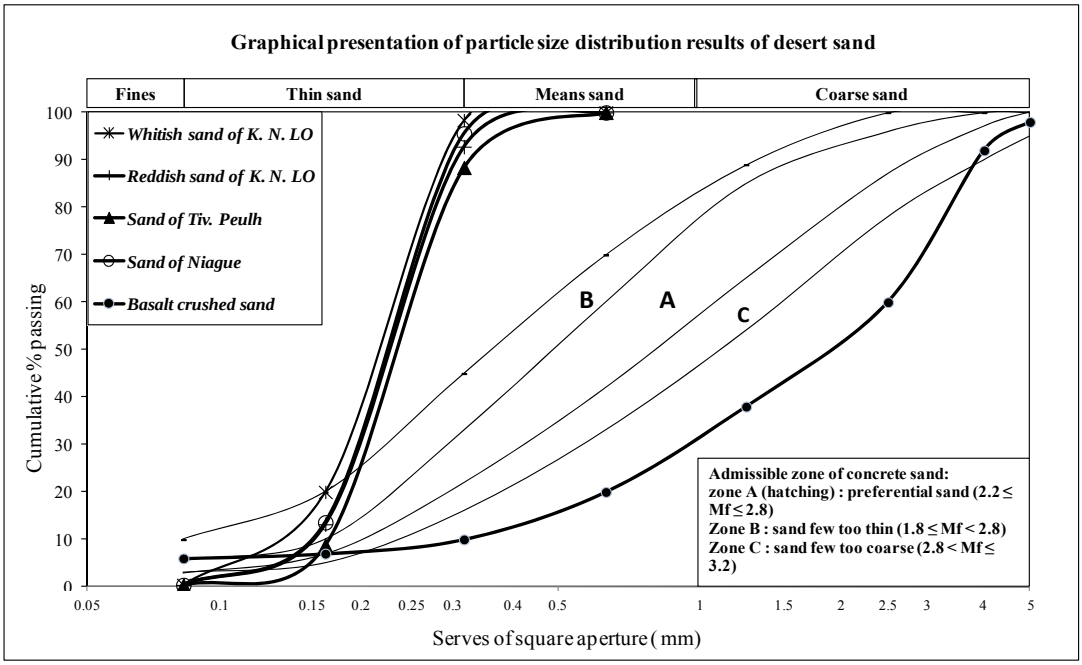

Fig. 2: Grading curves of desert sand from quarries of keur niaye lo, tivaouane peulh and niague

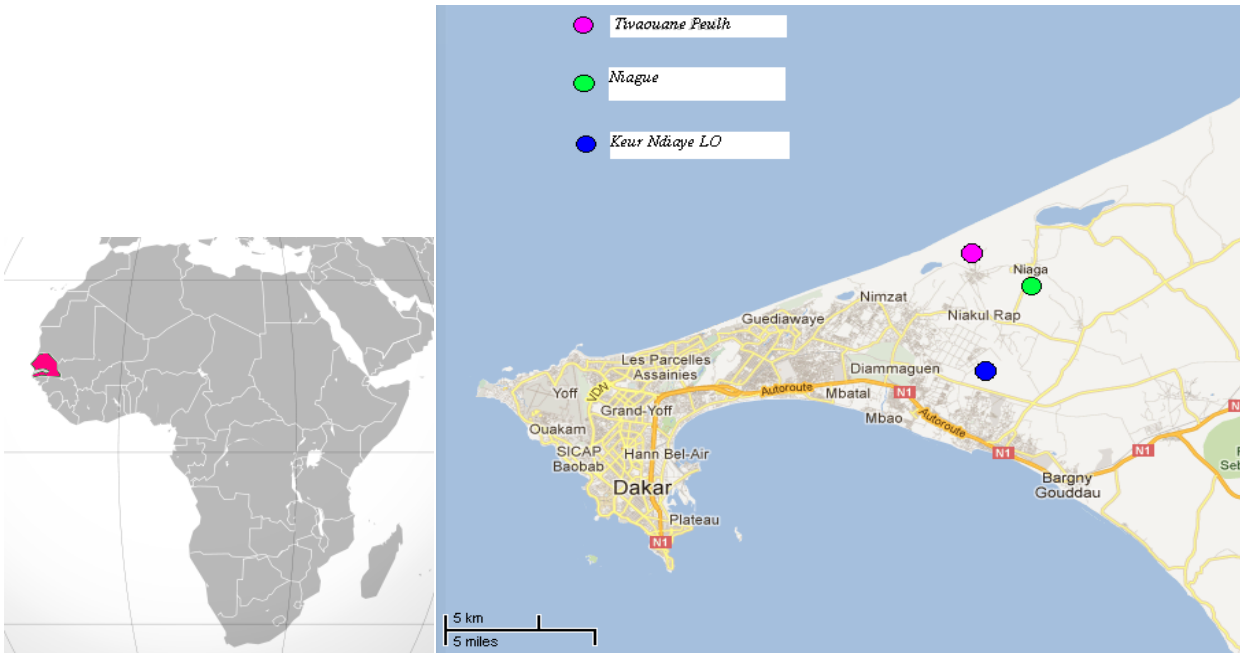

Fig. 3: Location of study sites

Keur Ndiaye LO has two types of sand: a reddish sand and whitish sand.

Test results of particle size distribution: The test involves passing a sample of granular material through a series of square mesh sieve, nested on top of each other. The dimensions of the openings are decreasing from top to bottom. The test result is then represented as a grading curve with sieve openings of the abscissa on a logarithmic scale and the percentages of tamisats ordinate, on an arithmetic scale. The granulometric tests were conducted according to standard EN 933-1 norm (Brussels, 1997).

Presentation of grading curves (Fig. 2): The granulometric analysis of the results uses the following remarks:

- Sands from each of these quarries are very thin. They are all out of time for selected granular sand concrete (Dreux, 1981).
- The Hazem uniformity coefficient (Cu = D60/D10) is less than 2 for all samples studied, which means that these materials are very tight-grained.

Determination of fineness Modulus (Mf): This is an important characteristic for concrete sand and is determined from the results of particle size analysis by sieving. The more or less the end of a sand is quantified by its fineness modulus. This is even smaller than the granules are rich in fine particles. According to NF P 18-540, the fineness modulus of sand is the sum of the percentages of cumulative retained, reduced to unity, for the sieve with 0.16, 0.315, 0, 63, 1.25, 2.5, 5 mm, respectively:

$Mf = 1/100 \Sigma CR$ % sieves (0.16, 0.315, 0.63, 1.25, 2.5 and 5 mm, respectively)

Much research has outlined some of time granularities eligible for sands (Dreux, 1981, 2007):

- **Mf<1.8:** The sand should not be used in concrete composition
- **For 1.8≤Mf<2.2:** The sand can be used if you are looking particularly ease of implementation at the expense of likely resistance (Zone B, Fig. 3)
- **For 2.2≤Mf<2.8:** Optimal value; this sand is suitable for a satisfactory workability and resistance to segregation with limited risk (Zone A, Fig. 3)
- **For 2.8≤Mf<3.2:** Is the oil to use for finding high strengths, but we will generally have a lower risk of workability and segregation (Area C, Fig. 3)
- **For Mf≥3.2:** The sand is too coarse and cannot be used in concrete composition

The values of fineness modulus given in Table 1 show that these desert sands have poor geotechnical characteristics for use in concrete composition. Their fineness modules are below the minimum required value (1.8) and the recommended optimal values (2.2 to 2.8).

Yet today, many building professionals are using these sands without any improvement. This results in insufficient resistance of concrete both in tension and compression.

Table 1: The values of fineness modulus following were found on the desert sand studied

Quarries	Keur ndiaye lo		Tivaouane peulh	Niague
Sand	Whitish	Reddish	Whitish	Whitish
Mf	0.82	0.94	1.03	0.91

Table 2: Sand equivalent values obtained on the desert sand

Quarries	Keur ndiaye lo		Tivaouane peulh	Niague
Sand	Whitish	Reddish	Whitish	Whitish
ES (%)	82	76	92	94

The sand equivalent according to EN 933-8 (Brussels, 1999): The sand equivalent is used to characterize the cleanliness of the sand used in the composition of concrete. It consists of separating the fine particles (particle silty clay, vegetable or organic) from the sand of coarser elements. The value of sand equivalent of a material is even weaker than it is polluted by fine particles. The values given below are for the sand equivalent to the piston.

Technology of concrete, the following guideline values can be used (Dreux, 1981):

- **ES<60%:** Clayey sand, risk of shrinkage or swelling, to reject for quality concrete
- **60≤ES<70:** Slightly clayey sand, cleanliness eligible for quality concrete running when you do not particularly fear the withdrawal
- **Mf≤70<80:** Clean sand with low percentage of fines, ideal for quality concrete
- **ES≥80:** The sand is too clean with a near absence of fines. Its use can lead to refusal of concrete plasticity

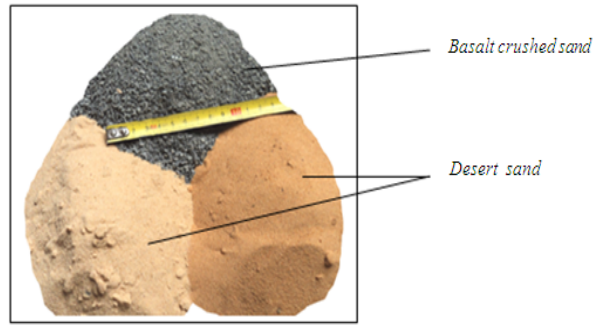

Fig. 4: Desert sands and basaltic crushed sand 0/3

The following results were found on different samples:

The values of Sand Equivalent found on desert sand are given in Table 2. The observation of these results show that the characteristics related to cleanliness is not satisfactory for these quarries except the reddish sand of Keur Ndiaye LO. Indeed, these sands are too clean and that would cause a lack of plasticity which would tend to be made up by mixing in an increase in water content which in turn would lead to lower mechanical strength of concrete.

IMPROVEMENT OF DESERT SAND BY BASALT 0/3

Sand 0/3 is a byproduct of aggregate crushing rocks. In this study, basaltic crushed sand 0/3 from the Diack quarry was used.

The desert sand was mixed with basalt sand 0/3 at varying levels (Fig. 4).

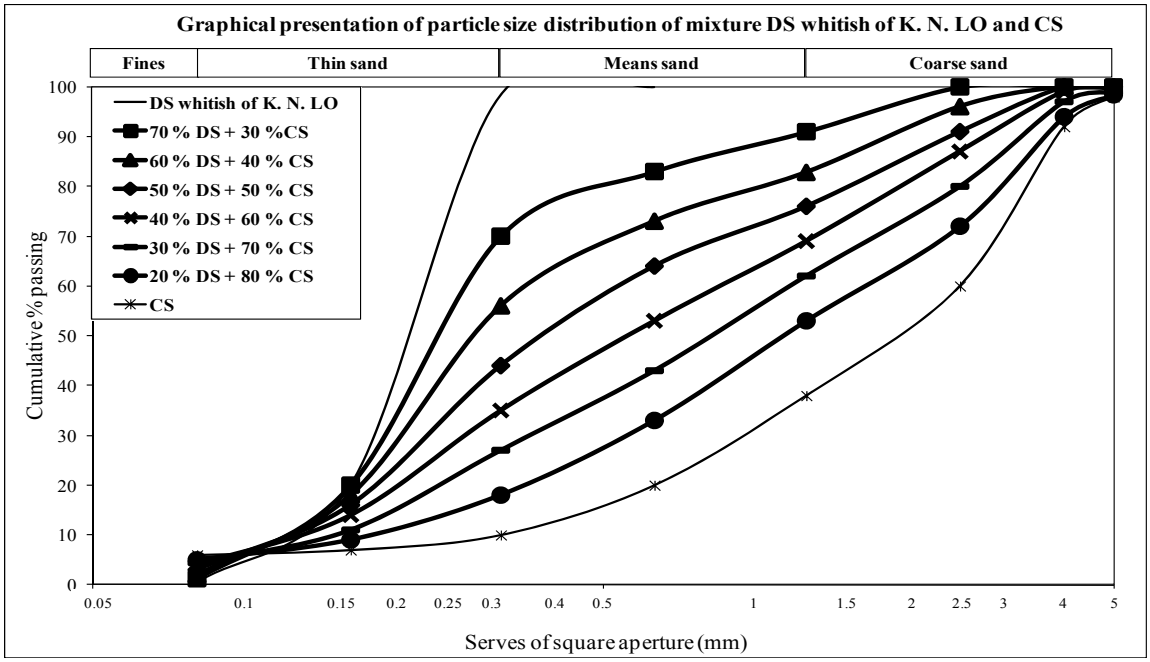

Fig. 5: Graphic presentation of particle size distribution in whitish sand gradation of K. N. LO mixed with crushed sand

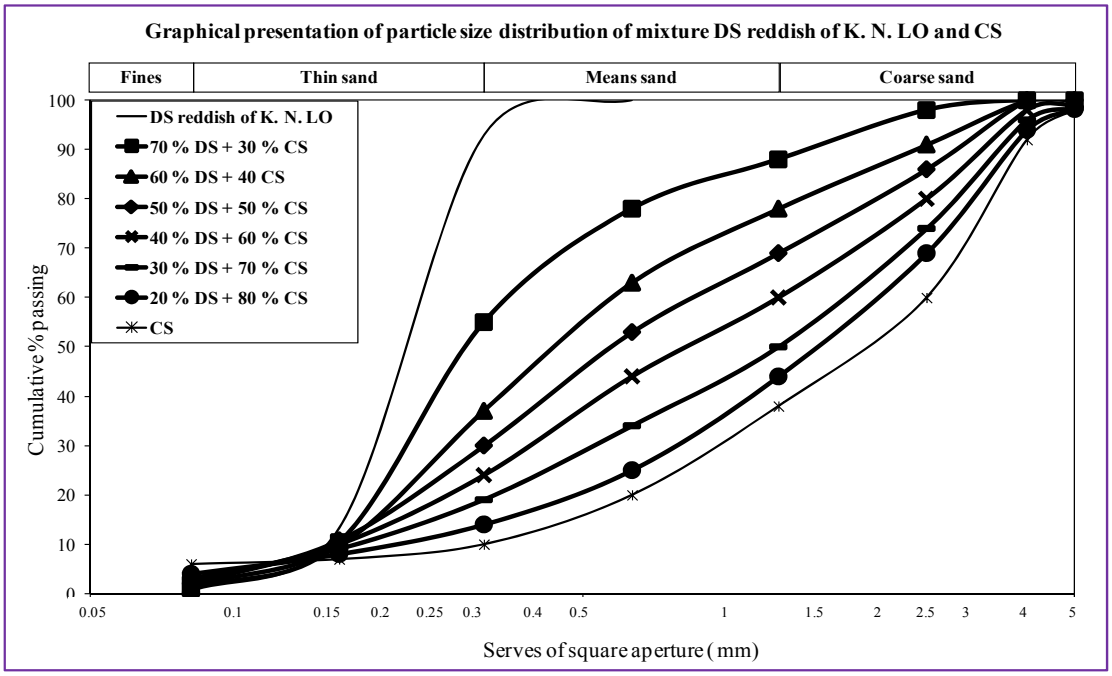

Fig. 6: Graphic presentation of particle size distribution of reddish sand K. N. LO mixed with crushed sand

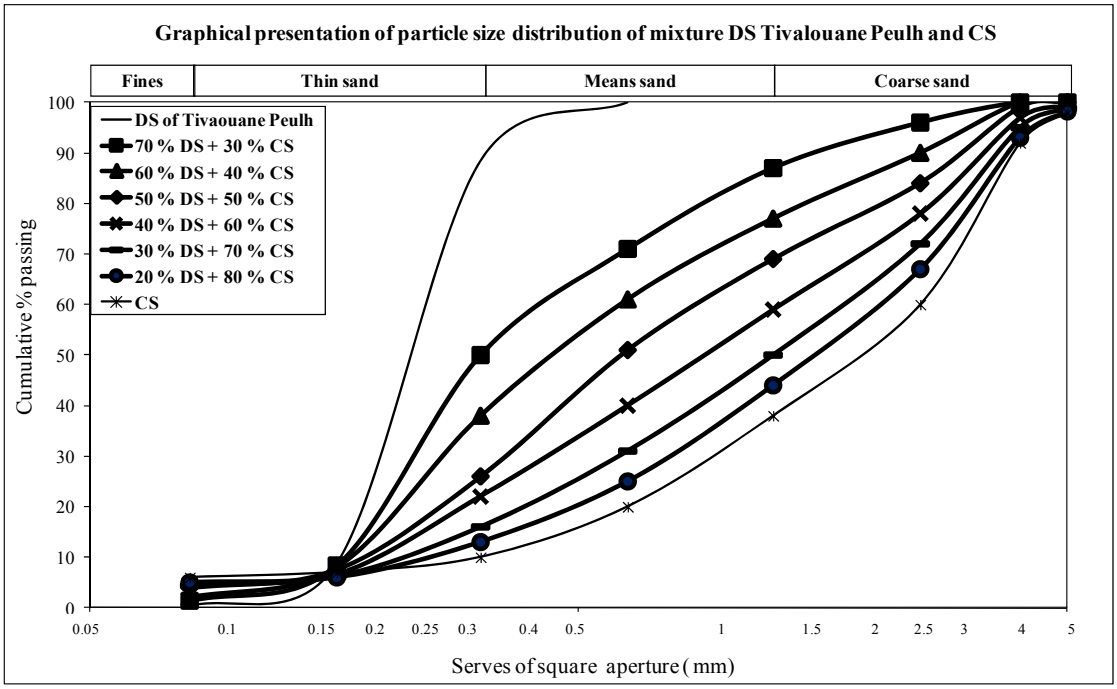

Fig. 7: Graphic presentation of particle size distribution of desert sand of tivaouane peulh with crushed sand

Test results of sand grain size improved:

Presentation of grading curves of sand improved: The following graphs give us the size distribution curves obtained on the desert sands mixed with basalt 0/3, with an increasing content ranging from 30 to 80%.

For figures, desert sand is designed DS and crushed sand is designed CS (Fig. 5 to 8).

By observing the Graphic presentation we can see that:

- Dimension of Grain size mixtures increases with the content of crushed sand
- The percentage of fines increases slightly with the content of crushed sand

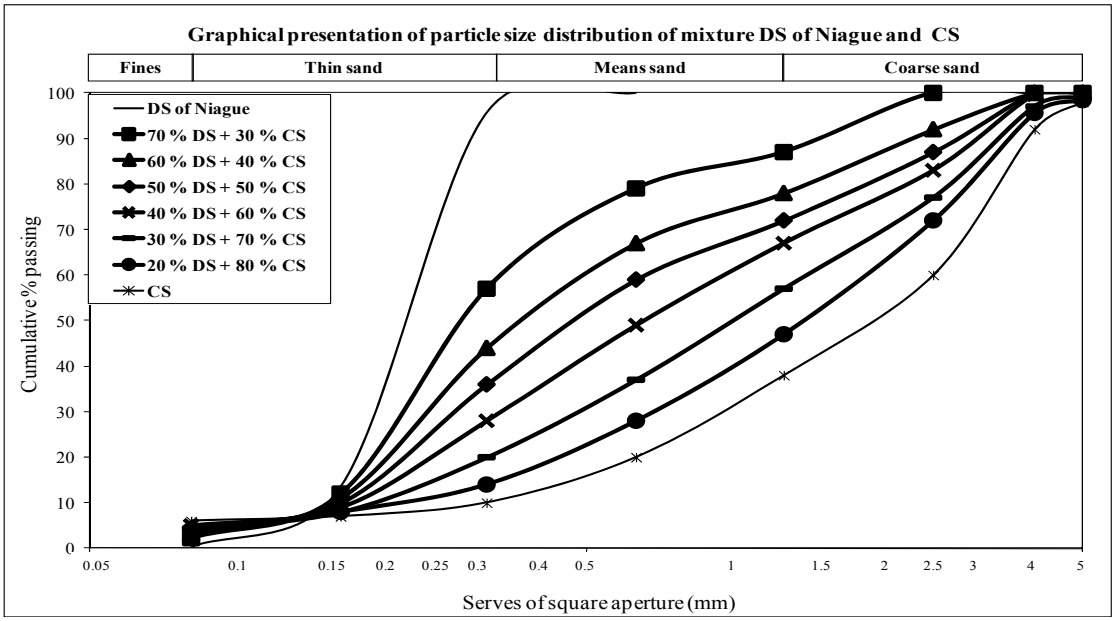

Fig. 8: Graphic presentation of particle size distribution of desert sand of niague mixed with crushed sand

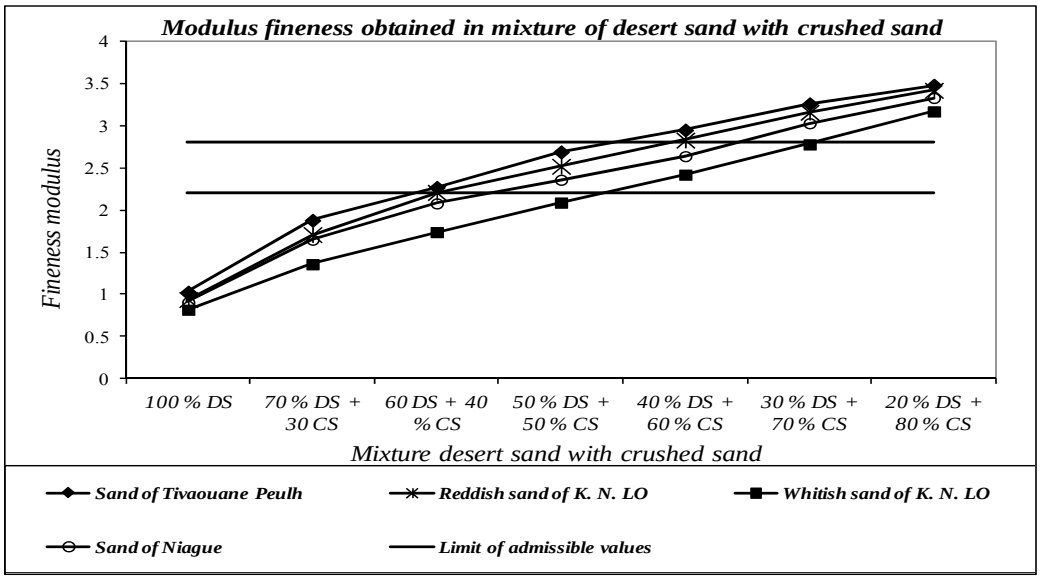

Fig. 9: Variation of fineness modules depending on the strength of crushed sand

- Particle size distribution curves become progressively spread as we add crushed sand

The fineness modules of sand improved: The fineness modules mixtures change with the content of basalt 0/3.

The following figure shows the growth of this module depending on the strength of basalt 0/3 for different sands studied (Fig. 9).

DISCUSSION

- The sand of Tivaouane Peulh gives a fineness modulus acceptable (1.88) with a mix of basalt crushed sand 30%. Optimum values of fineness modulus (2.27 to 2.60) are obtained on the sand with a dosage of basalt crushed sand between 40 and 50%.
- With the reddish sand of Keur Niaye LO, we obtain values of fineness modulus optimum (2.21 to 2.80) with a mix of basalt crushed sand between 40 and 50%. However, optimal values are obtained on the whitish sand of Keur Ndiaye LO with a mix of basalt crushed sand between 60 and 70%.
- The sand of Niague gives a value of fineness modulus with an acceptable mix of basalt crushed

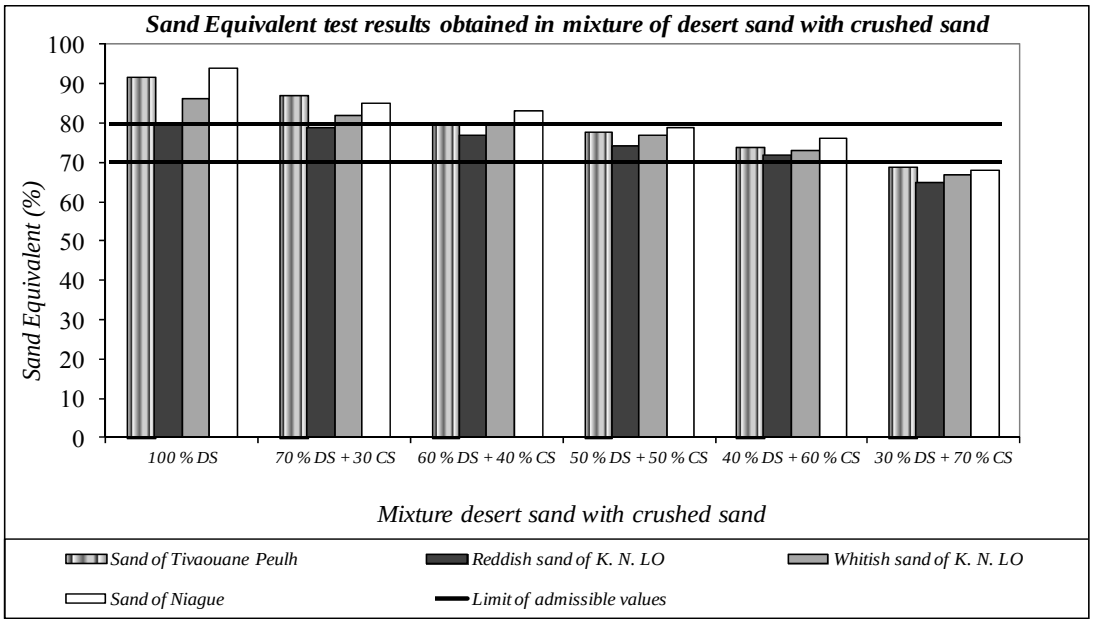

Fig. 10: Variation of equivalent sand depending on the strength of basalt crushed sand

sand 40%. Optimum values are obtained on the sand dosing with basalt crushed sand between 50 and 60%.

Results of tests performed on sand equivalent sands improved: Basalt crushed sand is used slightly rich in fine particles; sand equivalent is equal to 65%. The incorporation of this material in desert sand with very clean nature, gives a slight enrichment of the latter in fine particles. This improves the quality of aggregates for use in concrete composition (Fig. 10).

Discussion: Observation of sand equivalent results obtained on mixtures shows that:

- The sand of Tivaouane Peulh presents values of sand equivalent optimal with a dosage of basalt crushed sand variable between 40 and 60%.
- The reddish sand of Keur Ndiaye LO initially presents a good value of sand equivalent (76%) and retains this property to a mix of basalt crushed sand. The whitish sand of Keur Ndiaye LO presents optimal values of sand equivalent with a dosage of basalt crushed sand between 40 and 60%.
- The sand of Niague has good values of sand equivalent with a dosage of basalt crushed sand varies between 50 and 60%.

CONCLUSION

It appears from this study that the desert sand alone, from the quarries of Keur Ndiaye LO, Niague and Tivaouane Peulh, has not the characteristics of concrete sand. This is very fine aggregate (fineness modulus very small) and is very clean (equivalent sand very high).

Also, basalt crushed sand 0/3 is not only suitable for use in concrete composition. The latter has the opposite characteristics of desert sand as it is very coarse (very high fineness modulus) and is rich in fine particles (sand equivalent low). However, these aggregates, mixed with certain proportions, give good characteristics of concrete sand. By combining the results of the two characteristics studied (granularity, cleanliness), desert sands should be used with assays basalt crushed sand 0/3 the following:

- **Sand of tivaouane peulh:** (40 to 50%) basalt crushed sand
- **Reddish sand of keur ndiaye lo:** (40 to 50%) basalt crushed sand
- **Sand keur ndiaye lo:** (60%) basalt crushed sand
- **Whitish sand of niague:** (50 to 60%) basalt crushed sand
- A study for improvement of desert sand with other crushed sand or industrial products will produce other mixtures in favor of improving the quality of hydraulic concrete. In more, a research in other quarries of desert sand used in concrete composition can be interesting.

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