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New Formulation Method for Concrete Sand made with Dune Sand and Fillers from Limestone and Marble Industry by Product in Northern Borders Region of Saudi Arabia

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ABSTRACT: The aim of this study is to give an experimental protocol to obtain optimal filler's contents used as an additive in concrete sand (CS). Mining waste dune sand obtained from tabled tailing of the wet gravity concentration using the available Half-size shaking table is used. Two types of filler were considered: limestone (LF) provided from local crushing quarry waste and marble (MF). Maximum dry packing density is used to determine the different contents of the sand dune and fillers (LF and MF). To assure maximum mechanical resistances (compression and tensile), the needed fillers contents corresponded to the maximum dry packing density. The role of superplasticizer (in %) was also investigated by increasing the percentage from 0.5 to 2.5 by 0.5%. In addition, the rate of water and cement masses (W/C, cement content of 300Kg/m^3 was fixed for the set of performed tests) was varied with decreasing the W/C content by 0.1. The results show that the maximum dry packing densities respectively of LF and MF (175Kg/m^3 and 125Kg/m^3) conducted to the maximum mechanical resistances, to the minimum shrinkage deformation and to the optimum durability parameters; analyzed in terms of capillarity absorption and the chloride ion penetrability. Finally, the main challenge of the proposal study was the fillers waste recovery in sand concrete as an environmental alternative technical solution. This was reached basing on various mechanical, physical and chemical tests.

Keywords: Concrete Sand, filler, Dry Packing Density, Dune Sand, Limestone, Marble, Formulate.

Abbreviations: CS, Concrete Sand; LF, limestone filler; MF, marble filler; LFCS, lime stone-filler-concrete sand; MFCS, marble-filler-concrete sand; SP, superplasticizer; PDD, packing dry density; PD, packing density; DST, dune sand tailing.

I. INTRODUCTION

Like many parts of the world, the Northern Saudi Borders is characterized by vast region covered by dune sand. The Al Dahnaa deposits are almost 1,000 km long and 40 to 80 km wide to cover an area of 45,000 km2, or about 7.1% of the total Saudi Arabia. A new project for upgrading economic minerals from sand dunes can produce a large amount of salvaged sand that can be well-valued for sand concrete production.

Of the wide variety of concretes, concrete sand is particularly prominent. This fine-grained structure combines sand, cement, natural or industrial filler, superplasticizer and water. This mixture has established itself as a useful and effective type of building material.

Sand concrete therefore appears to be a suitable substitute material. The convenient formulation gives rheological and mechanical characteristics equivalent to those of conventional concrete. Moreover, the use of sand concrete as a replacement for conventional concrete can constitute an economically interesting variant of a rigid structure when the sand is easily accessible and at a lower cost comparing to common aggregates [1].

Sand concrete is fine agglomerate composed mainly of sand, fine addition, cement and water. Other admixtures are possible to improve physico-mechanical proprieties as needed [2, 3].

Most of authors clearly highlighted that whatever the type of sand used; the density of concrete (and therefore its compactness) increases with the increase in the quantity of fillers. The gain in compactness is always accompanied by a gain in resistance [4-6]. One of the most used filler is the limestone which is capable to create epitaxial bonds with the cement Unikowski, 1981, likely to be integrated into the cement paste, which itself consists of about 80% of limestone. Moreover, it is environmentally friendly as a local aggregate from the waste of the local rock crushing industry [7].

Several studies [8-14] carried out on the use dune sands in concrete mixing, show that this material has a very fine grain size, conducting to a significant shrinkage of the concrete. Associated with the hot and dry climate characterizing the Saharan zones, this phenomenon is amplified further, thus being able to negatively influence the durability of concrete. Indeed, the reduction of the durability of concrete is one of the major problems caused by severe climatic conditions with very high temperatures [15].

Since conventional concrete's porosity is less than the sand concrete one; to advance the granular skeleton's packing capacity, fillers are proved useful [8]. In addition to optimize the amount of cement, fillers are used; this also helps to differentiate both mortar and sand concrete. The types of the filler, fineness, and dosage have a significant impact on the hardened and fresh sand concrete's properties. Normally, semi inert or inert hydraulic and pozzolanic aggregates of lesser dimension 80 µm are ideal as filler to maintain and improve the segregation resistance and cohesion of concrete [16].

Khay *et al*., (2010), explored efficiency of shrinkage for Compacted Sand Concrete (CSC) which is composed of desert sand where the grain sizes were in the range of (0.08-0.8mm).Achieved outcomes validated the effectiveness of CSC in applied pavement applications [17]. The limestone impact as filler on the concrete's properties (mechanical) composed of dune sand, 1.18 fineness modulus is investigated in the study presented by Bédérina *et al*., (2005), [7]. The results indicated that as the limestone filler and cement content were 200kg/m^3 and 350kg/m^3 correspondingly, the dune sand concrete's strength of compression could reach 16 MPa. Furthermore, to manage the impact of sand(dune) as fractional replacement for river sand having unique parts on Flowing-Sand-Concrete (FSC) properties, limestone-type powder as filler used by Benaissa, *et al.,* [18]. The validation outcomes showed that the dune sand optimum content (satisfying FSC properties) was approximately 10% of entire sand by mass. Belhadj *et al.,* (2016), studied sand concrete composed of dune, river, crushed and river-dune sand with filler (limestone). They established that sand concrete properties (physical and mechanical) were impacted by the sand's physical-properties for example size distribution, maximum diameter and angular shape. For arid environment, sand concrete (Eco-lightweight) was lately developed by adding locally available barley straws. Its ductility, thermo physical properties, deformability and toughness as compared to sand concrete were enhanced [19].

Some studies have inspected the uses and compared as filler among FA and GGBS in the sand concrete [6]. Since the widely used artificial volcanic materials, their accessibility worldwide can deliver economic, social and environmental benefits. Furthermore, few researches exist on sand concrete's micro-structural characteristics like porosity and pore size distribution.

Owing to the inadequacy of the obtain ability of bulky quantities of sand and coarse collections in several regions throughout the world, significant increase in interest has been noticed in sand concrete development as replacement of regular concrete in civil (structural) engineering [20].

Banfill and Carr, (1987), explored impact of pure sand scoured from river bays on mixture of concretes [21]. It was established that water required for work increases if the content of sand increases. Nevertheless, it was observed that water contents for standard workability are not greater than the concrete composed of coarser sand. It was seen that elasticity and strength development are same as conventional concrete. Kay *et al.,* (2010), also studied the possible dune sand usage in concrete as satisfactory aggregates [22]. A comparison was investigated between mixtures of concrete composed of wadi, beach, screened dune, dune sand and mixtures of crushed rock fines with dune or screened dune sand. Results showed that dune sand in concrete as aggregate may deliver an alternate material for usage.

Laquerbe *et al.,* 1995, investigated the impact of using dune sand and laterite gravel for concrete as aggregates. Mechanical and physical properties of the unique aggregates as well as concrete strengths in tension and compression were investigated. The results indicated that laterite gravels can be alternate of limestone or basalt and offshore sand can be substituted by dune sand. In Oman desert region, few projects of construction have exercised concrete which is composed of dune sand (ranging 20-45% fine aggregates) [23].

From all this study it is clear that the mixing design of sand concrete is the main goal. Otherwise, the problem posed for its use remains. Then, traditional formulation methods have obvious limitations [24].

Different approaches have already been considered to apprehend the strength characteristics of sand concrete. One of the most method is presented in the French literature in the national project SABLOCRETE (94) [2], origin of the revised standard P18-500.The authors who have studied this material have adopted different approaches based exclusively on trial and error [25-29].

Bederina 2005, [4] use: a dune sand (DS), a river sand (RS), and a mixture of dune and river sand to study the possibility of exploitation of local sand to produce more workable, more compact and more resistant concrete sand. To determine the mass volume of the mixture they use the dry packing density by fixing the cement content and for every amount of filler (F) selected, the mixture is completed by adding sand until obtaining a volume determined after dry mixing and 15 s of vibration on a vibrating table. This method is called the packing dry density which aims to study the maximum compactness of the different aggregates of the mixture in order to minimize the intergranular voids, in a general way it is assumed that the finest aggregates are housed in the intergranular voids of the coarser aggregates.

The packing density can have a significant effect on the quality of hardened concrete. Maximum packing density will minimize the W/C ratio with improved flowability of the fresh mixture, other than it also contributes to the improvement of the mechanical properties [30-32].

Jiang *et al.,* (2018), used this method to determine the maximum of dry packing density of super fine sand with an optimum of GGBS 200kg/m^3. The author obtained a concrete sand with compressive strength at 28 days equal to 36 MPa, while fixing, a cement dosage of 300kg/m^3, a ratio W/B=0.45 and sp=0.5% [6].

In the other hand, Huan HE, (2012), studied the effect of compactness and shape of additions on proprieties of cementitous pastes, and concluded that the packing density increases with the vibration time then the mechanical propertiesof the mixing [33].

Gadri, (2018), Formulate a sand concrete by direct substitution of crushing sand with limestone filler. This study showed that we can optimize mechanical and rheological proprieties of CS by modifying the superplasticizer and W/C ratio [34].

After going over all this studies we noticed the impact of the vibration time on the final results of DPD. The vibration time has a great effect on dry packing density, so increasing the time of vibration can clearly increase the PD of each component than the DPD of the total mix [35-36].

This paper presents a new simple methodology to determine the maximum dry density. Fixing the cement content, mechanical compression and three bending tests were performed using variable additive content as superplasticizer content (SP), while the rate W/C was also varied. Evidently, only one variable was considered as long as the other external ones were fixed. Tests of durability were performed in order to highlight that the concrete dune-sand prepared according to the proposal experimental protocol has a convenient durability characteristic. Two fillers were tested and added according to the proposed protocol. Comparison between their issues interms of mechanical resistances and durability of the obtained sand-dune concrete is given and the performances were discussed.

II. MATERIALS AND METHODS

A. Materials

1. Dune sand Waste

Al Dahnaa sand dunes contains some important heavy economic minerals especially those of iron titanium and zirconium. To obtain most of the economic minerals from the dune sand a process of wet gravity concentration using the available Half-size shaking table will be performed. A tabled concentrate is obtained containing the majority of economic minerals and a tablet tailing almost free of most of heavy minerals. This tabled tailing of the wet gravity concentration corresponded to the sand used in all the mixtures for our study. It is characterized with relatively coarser-grain sizes and composed essentially of quartz with minor calcite and dolomite gangue minerals.

The chemical composition of the sand was determined by the scanning electron microscope SEM.

The sieve analysis of this sand was performed according to the ASTM C136 C136M 14 Standard Test Method, and was shown in Fig. 1. The physical and chemical characteristics of the sand are shown in Table (1).

2. Cement

All mixtures were realized with only Type I/ Ordinary Portland Cement (OPC) 42.5 from Northern Region Cement Co. The cement content was fixed to 350 Kg/m^3. Thus, the quality of this cement constitutes a constant at the level of the study parameters. Its chemical and physical analyzes provided by the producer are given in the Table (1).

3. Fillers

These are 2 by-products of the local industry of limestone, marble. Limestone filler is available in the majority of Arar quarries. The Marble filler is by product from local industry of marble production. The two fillers are obtained by softening (sieve 80µm). They have the following physical characteristics presented in the Table (1). The grain size distributions of these fillers are presented in Fig.1.

4. Superplasticizer

We used an ARCrete SP145M1 superplasticizer, it is a High-Range Water Reducer locally used by the concrete industry to improve the slump properties of concrete, and to improve the ultimate compressive strengths also it improves the flow and strength development of concrete as it is highly flexible and effective over a wide range of cement contents and types.

Appearance: Dark Brown Liquid
Specific Gravity: 1.175at 20°C
Air Entrainment: 1% Max from Control Mix.
Chloride Content: Nil according to BS5075

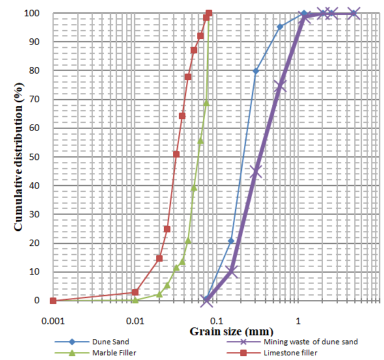

Fig. 1: Sieve analysis (a) Original dune sand, (b) Waste dune sand (c) Limestone filler and (d) Marble filler.

Table 1: Chemical compositions and the physical properties of OPC, Dune sand, Limestone Filler and Marble Filler.

Composition (wt%)	Cement OPC	Dune Sand	Mining waste sand	Lime stone Filler	Marble Filler
MgO	1.42	2,9	1.66	2,2	3,89
AL_2O_3	5.55	6,25	4.67	0,84	2,24
SiO_2	20.03	76,5	85.08	7,5	6,7
SO_3	2.83	–	–	0,15	0,1
Cl	0.08	0,02	–	0,01	0,01
K_2O	–	0,95	0.41	0,15	0,12
CaO	64.18	6,36	5.9	55,68	66,21
Na_2O	0.46	0,5	–	0,02	0,01
TiO_2		0,75	–	–	–
Fe_2O_3	4.18	4,3	2.28	–	–
PeO_5	–	0,02	–	–	–
Others	–	1,75	–	–	–
L.O.I	–	–		33,45	20,72
Specific gravity	3.10	2,64	2.68	2,71	2,74
sand equivalent	–	96,5	96.5	–	–
Fineness Modulus	–	1.04	1.71	–	–

B. Experimental methods

1. Methodology

Dry Packing Density:

Dry Packing Density is used by Chauvin *et al.*, (1996), Bédrina *et al.,* (2000), Jiang *et al.,* (2018) and Li *et al.*, [4, 6]. This method is summarized as follow:

- Fixing the dosage of cement and selecting the amount of filler in definite volume V,
- Filling the rest of volume with sand,
- Mixing and vibration for time t=3min
- Repeat the 3 process until the volume is totally fill and no decreasing after vibration.

This process is repeated for new amount of filler until reaching the maximum DPD.

On the other hand, to reach the optimal of filler content we propose a different protocol as it is summarized as follow:

- For the dosage of cement (350Kg/m^3), we determine the needed quantity of dune sand to complete the total volume V after mixing and vibration for time t=3 minute,
- Adding first amount of filler,
- Mixing and vibration for t=3min,
- Determining the Dry Density of the mix,
- Adding more filler with small quantity 5kg/m^3,
- Mixing and vibration for t=3min
- Calculating the dry density for the determined volume,
- Repeat the process until the DPD decrease,
- In a fixed volume V, adding the cement (350Kg/m^3) with the determined optimal amount of filler,
- Adding sand, mixing and vibrating for the same time and repeat this step until the volume V is totally filled and no decreasing after vibration.
- Calculating the Maximum of dry packing density.

2. Sample preparation

After determining the maximum of dry packing density, we proceed to study the effect of fillers content, SP and W/C on the different obtained mixture.

The workability of the mixes is controlled with the slump test according to ASTM C143, which is taken ≥60mm.

Table 2: Mix proportion for concrete sand preparation.

N°	Cement (Kg/m^3)	Dune Sand (kg/m^3)		Filler (kg/m^3)	W/C	SP%$^{(a)}$	Slump Test (mm)
		Limestone filler	Marble filler				
Initial mix preparation							
S0	350	1670		0	0.65	0.5	80
Filler effect mixtures							
S1	350	1648	-	50	0.65	0.5	90
S2	350	1619	-	100	0.65	0.5	92
S3	350	1585	-	150	0.65	0.5	105
S4	350	1568	-	170	0.65	0.5	114
S5	350	1517	-	200	0.65	0.5	119
S6	350	1415	-	250	0.65	0.5	125
S7	350	1307	-	300	0.65	0.5	135
S8	350	-	1637	50	0.65	0.5	96
S9	350	-	1596	100	0.65	0.5	103
S10	350	-	1573	125	0.65	0.5	110
S11	350	-	1540	150	0.65	0.5	115
S13	350	-	1438	200	0.65	0.5	130
S14	350	-	1330	250	0.65	0.5	136
S15	350	-	1215	300	0.65	0.5	142
S8							
S16	350	1568	-	170	0.65	1	112
S17	350	1568	-			1.5	125
S18	350	1568	-			2	140
S19	350	1568	-			2.5	152
S20	350	-	1573	125	0.65	1	121
S21	350	-	1573			1.5	132
S22	350	-	1573			2	148
S23	350	-	1573			2.5	158
W/C effect							
S24	350	1568	-	170	0.59	2	137
S25	350	1568	-		0.58		131
S26	350	1568	-		0.57		128
S27	350	1568	-		0.56		124
S28	350	-	1573	125	0.59	2	140
S29	350	-	1573		0.58		137
S30	350	-	1573		0.57		130
S31	350	-	1573		0.56		126

$^{(a)}$By weight of binder (Cement+filler)

C. Testing methods

1. Compression strength

The characterization of the compression strength was carried out on water-ripened cubic specimens of (5×5×5cm^3) in accordance with the ASTM 109/C109M–08, standard. The results of the compressive strength were measured at 7, 28 and 90 days. Each strength value presented here corresponds to the average of three measured compression strength values.

2. Three points bending tensile strength

The characterization of the tensile behavior is characterized by flexural tensile test carried out on water-ripened (4×4×16 cm^3) prismatic specimens. The evolution of the tensile strengths is followed by tests at 7, 28 and 90 days. Each tensile strength value presented here corresponds to average of three tensile bending values.

3. Capillary absorption

The 10 × 20 cylindrical specimens are kept in water for 28 days, and then cut into a 5 cm thick cylinder. Finally, all the specimens are dried in an oven at a temperature of 60°C for 5 days in order to remove all the humidity. To ensure unidirectional flow the lateral side of each specimen was covered by paraffin wax, the top side of specimens was covered with plastic sheet to stop any evaporation. According to ASTM C1585-04, each specimen was weighted every 0, 1, 2, 4, 8, 24, 36, and 72h to determine the mass of absorbed water then plotted against the square root of time (Fig. 2.).

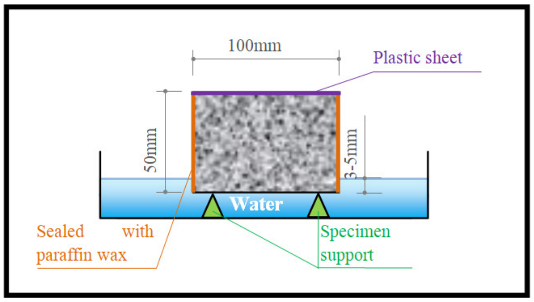

Fig. 2. Capillary absorption test (ASTM C 1585–04)

4. Rapid chloride penetration test RCPT

This test is performed in accordance with ASTM C1202 Standard, to evaluate the Concrete's Ability to Resist Chloride Ion Penetration, and to check quality and permeability in short time for durability-based quality control purposes. After 90 days of moist curing, three 2-in. (51-mm) thick slices of 4-in. (102-mm) nominal diameter cylinders for each mixture. The specimens were putted in a vacuum chamber for 3 hours, and then were vacuum saturated for 1 hour and allowed to soak for 18 hours. Every specimen then placed between two cells. The left-hand side (–) of the test cell is filled with a 3% NaCl solution. The right-hand side (+) of the test cell is filled with 0.3N NaOH solution (Fig. 3).

In this test, the constant voltage (60 V dc) was applied on a concrete specimen for 6 hours and the current (i) passing through the concrete was recorded every 30 minutes to find the total charge passed, in coulombs which is related to the resistance of the specimen to chloride ion penetration.

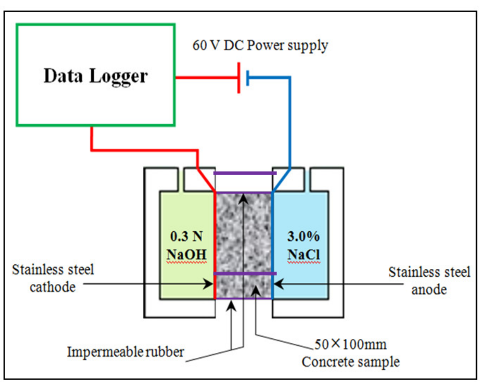

Fig. 3. Rapid chloride penetration test RCPT (ASTM C1202).

III. RESULTS AND DISCUSSION

A. Dry packing density

To prepare the DPD according to the proposal protocol as it is indicated above, the time of vibration was varied when the dry density was kept constant.

Some authors [33, 35] have been showed that the time vibration has a signification impact on the DPD so the time vibration was fixed in this study (180 sec) corresponding to the value for each the packing dry density remains constant.

The maximum filler content that can be incorporated into the intergranular voids was of 125 kg for marble and 170 kg of limestone filler. The maximum filler contents were respectively 10, 14% and 7.94% of sand (170kg for limestone filler and 125kg for marble filler).

In the case of concrete dune sand, it was demonstrated Jiang *et al.*, (2018) that the addition of filler is followed by a substitution of sand because the grain size of the dune sand is too fine and too tight [6].

It can be observed (Fig. 4), that the maximum of dry packing density for the limestone filler is more than that of the marbles maximum PD filler, this result is explained by the fact that limestone filler constituted by more finer particles comparing to the marble filler, in fact 90.19% of the marble grains has equivalent diameter between 38 and 80µm however 46.38% of the lime grains have an equivalent diameter <38µm.

The Same conclusion was presented by Jiang *et al.*, (2018) [6], when he used a super fine waste sand with the GGBS filler however to obtain the maximum DPD of 2085 kg/m^3 the authors used F/S=13.03% which is higher than the percentage of filler used in own research, it will be noted firstly that the authors used 300kg/m^3 instead of 350kg/m^3 of cement and secondly the used GGBS is well reactive filler.

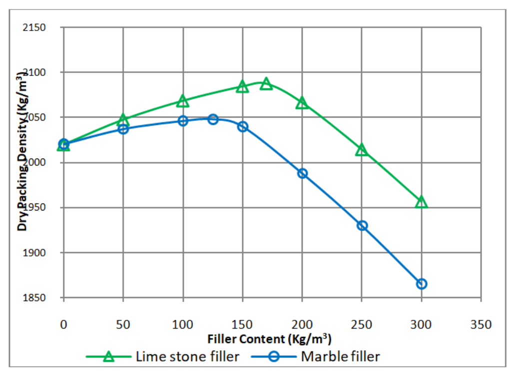

Fig. 4. Evolution of Dry Packing Density with fillers contents.

B. Compression and tensile strength

Uniaxial compression test was performed on the cubic specimens (5×5) with different filler contents using both limestone and marble fillers. The effect of superplasticizer and the rate of water content were studied. In addition to that indirect flexure tensile tests were performed to investigate the effect of same parameters.

1. Compression strength

(i) Effect of filler content

As it can be observed from Fig. 5 compression strength is maximum for the optimal DPD for both fillers; limestone and marble. The same trends were obtained for the cure time of sand concrete samples 7, 28 and 90 days.

As it was expected the increase of compression strength was more important between the cure time 7 days and 28 days in comparison the variation between 28 and 90 days.

Also, the compression strengths for limestone filler were higher than of those obtained with marble filler, this result is supported by the fact that for same filler content the DPD of the limestone filler-concrete sand is higher than the DPD of marble filler-concrete sand. As it was mentioned by Bédérina *et al.,* 2005, [7], that the maximum of compactness is achieved with the optimal filler content, which ensures a physicochemical activity and promotes the acceleration of the hydration of the Cement.

In addition, the presence of fillers clearly improved the granular packing of the mixture so it increases the cohesion of composites [37].

The challenging results in terms of compression strength values were reached for the both used fillers. Compression strength values of 25Mpa and of 20MPa for respectively LFCS and MFCS (at cure time 28days).

In comparison with the previous studies (Jiang *et al.,* (2018), Béderina *et al.*, (2005),) [6, 7] this encouraged results are well highlighted.

On the other hand, the increase in the addition of the limestone filler beyond this optimal content causes a relatively drop in compactness as well as resistance. Indeed, once the voids are completely filled, the fine particles begin to occupy the place of the grains of sand, and consequently, a decrease in the proportion of sand and the density of the mixture [35].

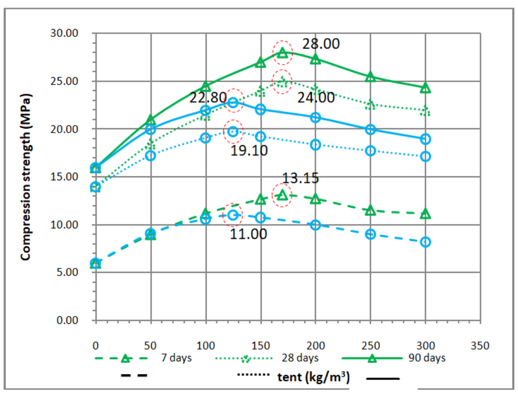

Fig. 5. Effect of filler content on Compression strength.

(ii) Effect of super plasticizer

Neville, 2000 claimed that the addition of super plasticizer increases mechanical strength at W/C ratio constant. Since addition of SP will improve and accelerate the hydration process by prohibiting the flocculation of cement and fillers particles. Modifying the Sp% acts favorably to improve compressive strength at all ages. In addition, the best compressive strengths are recorded at the age of 7, 28 and 90 days with SP = 2% for both the two fillers. This SP% offers an increase in strength by 20.68, 12.6, 19.65% for the LCS at 7, 28 and 90 days, and by, 26.09, 20.25 and 26.09%. Gadri, (2018), [34] find that for the same optimal percent of SP, an increase of the compression strength with 19% compared to the basic formulation of limestone filler and crushed sand (Fig. 6).

Beyond the optimal value of SP(2%) increasing SP will reduce the compressive strength. This is due to the bleeding and segregation which affect cohesiveness of concrete sand.

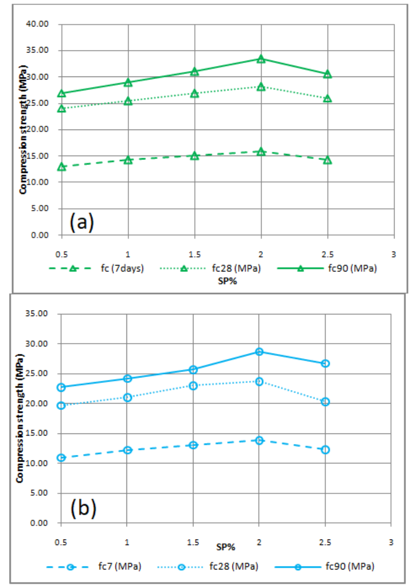

Fig. 6. Effect of Superplasticizer on Compression strength (a) Limestone-filler-CS (b) Marble-filler-CS.

(iii) Effect of W/C

From the Fig. 7 the optimal value of W/C is 0.58 for the LCS and 0.57 for the MCS. The decrease in mixing water increases the compression strength, but if we exceed the optimum value, any decrease results in a drop in compressive strength. The obtained maximum compressive strengths were 18, 30.2 and 37Mpa at 7, 28 and 90days and 16.02, 25.75 and 32MPa for the MFCS at the same ages. This is certainly due to the improvement in cohesion, by reducing the amount of water to the amount necessary and sufficient for hydration.

Gadri, (2018), noted that over an optimal W/C ratio of 0.6, the exceed of water decrease the cohesiveness and then the strength of CS.

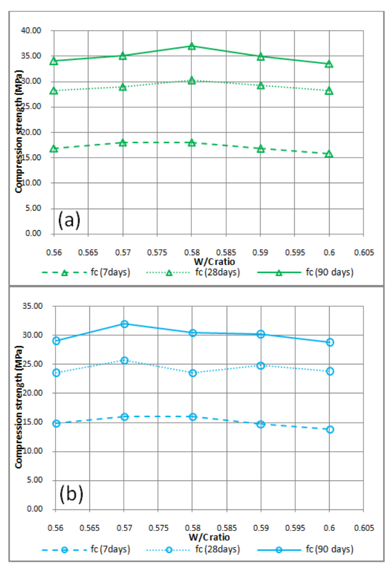

Fig. 7. Effect of W/C ratio on Compression strength (a) Limestone-filler-CS (b) Marble-filler-CS.

2. Three point bending Tensile strength

(i) Effect of filler content

Like observed for the compression strength the maximum tensile strength (obtained via indirect test) is obtained for the maximum of DPD for the two CS.

The tensile strength variation with filler amount is presented in Fig. 8. From these curves (7, 28 and 90 days) it's clear that the tensile strength increases with filler to reach a maximum for the optimal values of two fillers. For this optimal amount of fillers an increase of tensile strength by 0.76, 1.05, 1.15 MPa for limestone filler for respectively 7, 28 and 90 days. For the marble filler the increase is by 0.76, 0.75 and 0.77 MPa.

The values of tensile strength remain moderately low and represent approximately a percentage around of10% of the compressive strength at different cure ages (7, 28 and 90 days) for all mixtures.

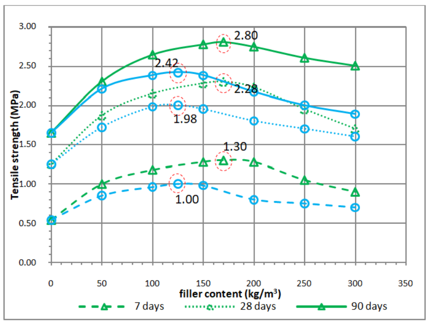

Fig. 8. Effect of filler content on tensile strength.

(ii) Effect of super plasticizer

From Fig. 9, the value of SP = 2% remains the optimal value leading to the maximum tensile strengths as it was for the case of compression strength, for both LS and LM fillers. Indeed, with LS the maximum tensile strengths were 1.45 MPa, 2.60 MPa and 3.60 MPa for respectively the cure time of 7, 28 and 90 days. However, with LM filler, maximum tensile strengths were 1.25MPa, 2.33MPa, and 2.78MPa.

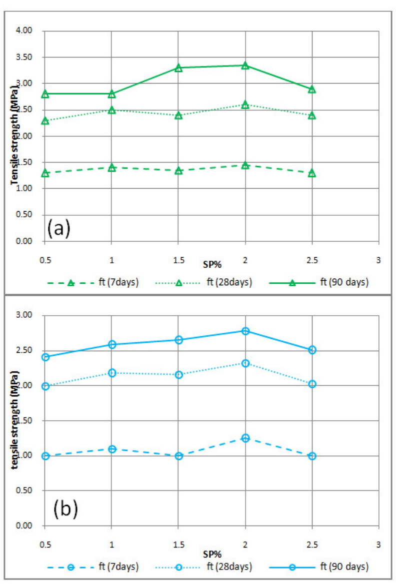

Fig. 9. Effect of Superplasticizer on tensile strength (a) Limestone-filler-CS (b) Marble-filler-CS.

(iii) Effect of W/C

The trends of tensile strength against the filler content considering the decrease of parameter W/C ratio are similar to those of the compressive strength, using separately the two fillers.

We can also notice that the maximum increase rates of the tensile strength were 10.44% with LFCS for W/C=0.58, and 11.33% with MFCS for the optimum W/C=0.57. These values were obtained at earlier age of curing (7days). Finally, from the Fig. 10 we note that the effect of the W/C on tensile strength remains moderate.

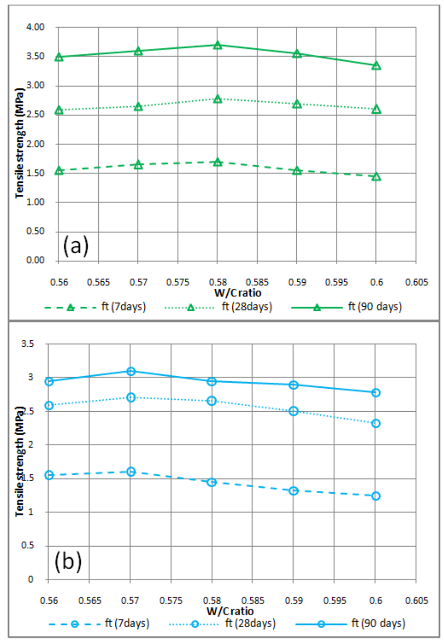

Fig. 10. Effect of W/C on tensile strength (a) Limestone-filler-CS (b) Marble-filler-CS.

3. Durability of the Concrete sand

To study the durability of the concrete using the two fillers two main experiences were conducted capillary absorption test and Rapid Chloride Penetration Test according to ASTM standards.

(i) Capillary absorption

By the same way, the effect of filling interstitial voids is again demonstrated from the results of capillary absorption presented in Fig. 11.

It is well known that adding filler leads to the porosity decrease witch conduct to capillary absorption potential decrease. Adding the both used fillers, as it was expected, the absorption rate increases with time to reach a constant value associated for each adding filler content. In fact, the minimum absorption rate was observed for both fillers with the optimum adding filling quantity (170, 125). These values can be considered as low (standard) and then the durability of studied concrete sand can be sustainable and also the optimum adding fillers quantity contribute to improve more the durability aspect.

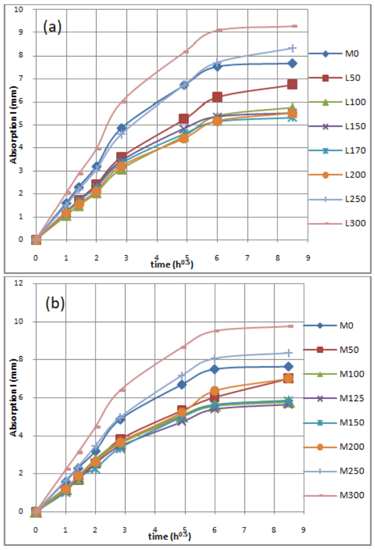

Fig. 11. Effect of filler content on capillary absorption (a) Limestone-filler-CS (b) Marble-filler-CS.

On the other hand, the role of superplasticizer was investigated for the both optimum filler contents, indeed, the percentage of SP varied from 0.5 to 2.5%, the capillary absorption rate was also minimum for the optimal content of SP=2%. These results support the fact that the optimum in terms of filler contents and superplasticizer percentage are optimum values to improve the durability (Fig.12).

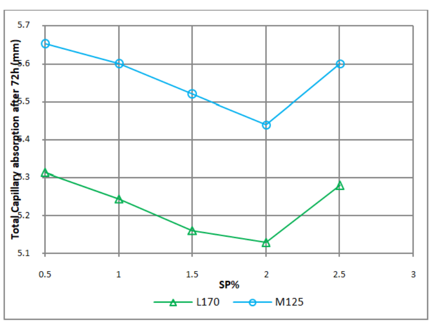

Fig. 12. Effect of Superplasticizer on total capillary absorption after 72h for optimum filler contents.

We note that the W/C ratio has the same trend effect as the filler content and superplasticizer. In fact, the W/C ratio of 0.58 for LFCS, give the minimum value of capillary absorption rate (Fig. 13).

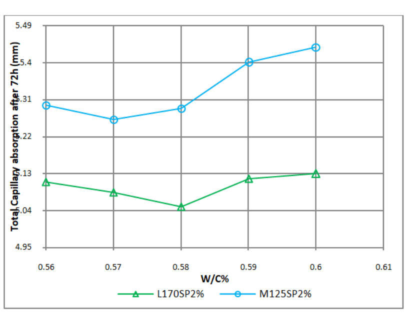

Fig. 13. Effect of W/C ratio on total capillary absorption after 72h for optimum filler contents.

(ii) RCPT Test

Regarding to ASTM standard the chloride ion penetrability should be less than 4000 Coulombs. In this study and using the two fillers, it was found that the minimum value of the total charge diffused was obtained also the optimum filler contents (Fig. 14), and for the optimum superplastizer and the optimums W/C ratios. In fact, when we fix the filler contents as optimum values (170 for LFCS and 125 for MFCS) and respectively superplasticizer rate of 2% and W/C ratios of 0.58 to 0.57 for MFCS, we obtain the minimum of total charge diffused (2160,5 for LFCS and 2392.11 for MFCS) which is more convenient to support the durability of the proposed formulation of concrete sand.

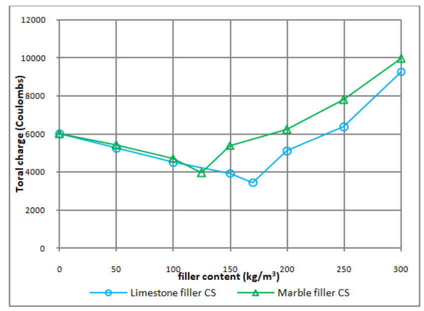

Fig. 14. Effect of filler content on total charge diffused in Coulombs.

Fig.15 and 16 give respectively variation of total charge diffused rate with respectively the filler content, the superplasticizer % and W/C ratio.

The inclusion of fillers provides improved pore system, thus increasing the resistance to the penetration of chloride ions [38].

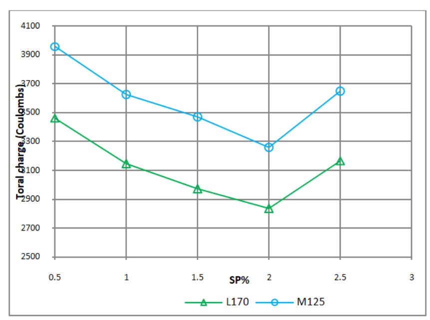

Fig. 15. Effect of Superplasticizer on total charge diffused in Coulombs.

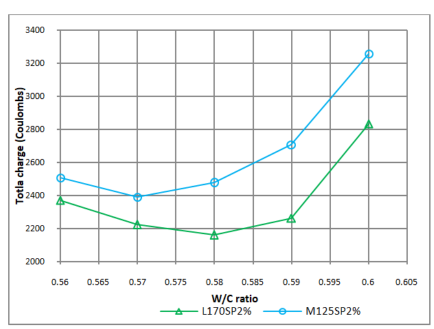

Fig. 16. Effect of W/C ratio on total charge diffused in Coulombs.

IV. CONCLUSION

Main conclusions from this experimental study can be addressed:

— The experimental protocol to reach the maximum dry density with adding filler was justified basing on all the required parameters for the concrete dune-sand.

— The dune sand considered here as a waste of a selection procedure of heavy minerals was valued to give convenient concrete sand according to the international standard.

— The compression strength was well improved using the two fillers, particularly with the limestone filler. More the filler's fines are filled in the pores, more the compression is improved.

— The durability of the proposed concrete dune-sand was well assured with the two fillers, and all the associated parameters are optimum for the specimens prepared at maximum dry density.

— Consequently, the preparing of the mixing according to the proposal protocol at maximum dry density, gives satisfactory required mechanical strengths (maximum compression strength of 35MPa and tensile strength) and physico-chemical parameters to assure the durability of the concrete dune-sand.

— One of the main challenges was to improve the environmental research, by the study of the waste recovery, as the mineral fillers and the dune sand use in sand-concrete. So, the sand concrete should be an alternative to offer both the engineering needs in terms of environmental constructions and the cost reduce.

V. FUTURE SCOPE

At the end of this work, it is interesting to use other filler such as a natural pozzolan filler, a quartz filler characterized by their pozzolanic reaction as a partial substitution of cement and sand. On the other hand, it is necessary to evaluate the effect of nanofillers on the physico-mechanical properties of sand concrete.

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