Experimental study on the phenomenon of cracking of a reinforced element in sand concrete

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Abstract. *With the diversity of concrete quality, sand has taken a big place in the composition of sand concrete. However, reinforced concrete based on sand is undergoing experimental tests and validation tests, and its cracking in this concept has become a very paramount parameter when sizing this material. In this context, this work of an experimental nature, has for main objective to study the cracking of an element of reinforced concrete based on sand by the variation of the spacings of cracks using a reduced model in reinforced concrete.*

Key words: sand concrete - Cracking - tensile test - average crack spacing.

1. Introduction

Sand concrete is an artificial agglomerate of sand, cement, water and possibly fines added from fillers. Sand concrete by its current design, are newly created materials, to replace conventional concrete [1].

Indeed, the abundance of sand in our country of Algeria requires more and more to use more to build civil engineering works, especially since the sand concrete being a special concrete in absolute majority is composed of sand [2]. In this context, our interest was concentrated in this new old material, since its creation dates from the 18th century and scientific research became involved in a multi-disciplinary interest just towards the end of the 19th century [3].

Note that the research that has been carried out on the cracking of materials can only concern limited cases and precise problems, hence the fairly wide field of the study of cracking and the large number of researches [4, 5, 6]. To know more about the behavior of cracks in the traction zone below the horizontal axis, This transition zone has an impact on the properties of the crack and is directly influenced by the steel-concrete interface [7, 8].

To this end, our experimental work consists in studying the cracking of concrete in the sand, (pulling case subjected to traction), this element will be made from local materials. In this problem, we took part in the study of this type of concrete in order to know its behavior to cracking when it is provided with reinforcements of steels. (I.e. towards qualification as much as reinforced concrete). And to start this study, We have developed another experimental program with pulling tests allowing the detection of the network of cracks in a clearer way compared to the bending tests. To do this, we created an experiment on small samples of dimensions (7X7X28) We also reduced the model to adapt it to the nature of the cracks closest to this targeted area [2, 9]. The pulling test is specially chosen to represent the stretched part in the area of constant moments of the four-point bending test.

2. Expérimental procédure

2.1. Used materials

As part of this experimental program, we used three types of sand of different nature and size. These are coarse (S_g), medium (S_m) and fine sand (S_f). Their physico-chemical characteristics are summarized in the table1.

Table 1. Physical characteristics of sand

Sand type	Units	Coarse sand	Medium sand	Fine sand
Absolute volumetric mass M_{ab}	g/cm^3	2.5	2.6	2.7
Apparent volumetric mass M_{app}	g/cm^3	1.71	1.57	1.51
Equivalent of Sand E_s	%	72.12	91.10	95.96
porosity	%	28.99	27.68	26.54
compacity	%	71.01	72.32	73.46
Fineness module M_f	%	2,06	1.19	0.51
Coefficient of uniformity C_u	/	5	2.8	2.11
Curvature coefficient Cc	/	0 .66	1.15	0.98
Color	/	Yellowish	Yellowish	yellowish red
Nature	/	Siliceous	Siliceous	Siliceous
form	/	crushed	rolled	rolled

The particle size curves, expressing the cumulative percentages by weight of the pass as a function of the size of the sieves. The results of particle size analysis of the three types of sand are shown in Figure 1. From this figure, we can observe that the grain size curve for the two sands (coarse and fine) gives a similar character. On the other hand, it badly graduated, and giving a well graduated and spread curve for the medium sand which was a crushed sand presented a well graduated but spread curve.

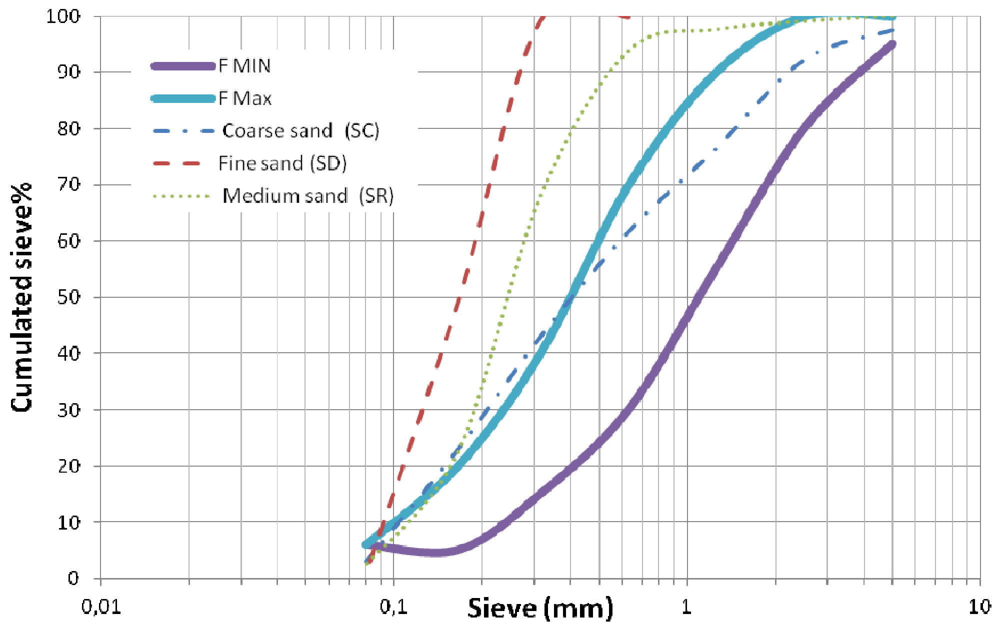


Figure.1 Particle size curve of the three sands used

Analysis of these curves, we can cite the following observations:

- ✓ Fine sand (SD) has a discontinuous particle size distribution; grains with a diameter between 0.63 and 0.5 mm are missing, so this sand is characterized by a dense particle size distribution.
- ✓ Coarse sand (SC) with a fineness module 2.06. Is at a position between two zones Min and Max, and that for the coarse elements, and the lower part confused with the zone Max.
- ✓ Medium sand (SR) is a sand rich in fine elements, due to the fact that the particle size curve below the maximum time zone.

A single type of cement was used for the preparation of all of the elaborate sand concrete compositions. It is CPJ-CEM II/B 42.5N cement which conforms to the standard (NFP 15-301/9). The physico-mechanical characteristics are summarized in Table 2.

Table 2. Physical characteristics of cement

characteristics	Absolute volumetric mass (g/cm^3)	Apparent volumetric mass (g/cm^3)	Normal consistency (%)	Beginning of setting (h/min)	Fineness of grind	compressive strength at 28 days (MPa)	tensile strength at 28 days (MPa)
Values	1,057	3,20	29	2h34min	9,60	39	07

Only one adjuvant was used as a super water-reducing super plasticizer. This is MEDAPLASTE SP40 brown in color, their density is equal to 1.2 g / cm3, and with a PH = 8.2. In contrast, the addition of MEDAPLAST HP was used as a powder addition, it is characterized by a density of 0.5 g / cm3, a mass area greater than 15 (m2 / gr), a humidity per oven at 105 ° C of less than 1%; with a particle size of less than 0.1 microns. Its chemical composition shows the percentages of: SiO2> 8.5 (%); SO3 <2.5 (%); Cl <0.2 (%).

Two types of stell bar were used in the manufacture of reinforced sand concrete specimens. These are high-adhesion and smooth round frames, chosen according to four diameters respectively (10mm, 12mm, 14mm and 8mm). The mechanical characterization of the different steels used is shown in Table 3. It should be noted that the presented values of the elastic limit, the breaking stress and the modulus of elasticity are obtained with the average of three measurements. It is interesting to mention that we cannot exceed 14mm because the test device does not allow for larger diameters.

Table 3. Mechanical characteristics of the steels used

Ø [mm]	Type	Tensile stress on steel [MPA]		E_s [MPa]
		Elastic limit fe	Break fr	
10	HA	564	623	210200
12	HA	612	667	210000
14	HA	610	729	197300
8	RL	293	413	210530

2.2. Formulation and implementation of elaborate concrete

The composition method used in this sand concrete study is the so-called experimental one. where the water dosage is developed by setting the cement dosage with the W / C ratio, and we vary the dosage of sand in such a way as to obtain a workable concrete to finally reduce this quantity to the estimated workability. After mixing, it is possible to obtain a dry confection, We seek for each mixture the quantity of water necessary to ensure a maneuverability fixed beforehand, because the W / C ratio is increased until a more manageable sand concrete is obtained [2, 10].

Table 4 brings together the different compositions.

Table 4: Different composition of sand concrete

reference	W/C	Cement (kg/m^3)	Water (l)	Adjuvante (l)	Silica fume (kg/m^3)	Coarse sand (kg/m^3)	Medium sand (kg/m^3)	Fine sand (kg/m3)
BSC	0.9	350	315	8.75	20	1328.67	-	-
BSR	0.9	350	315	8.75	20	-	1434.98	-
BSD	0.9	350	315	8.75	20	-	-	1381.82

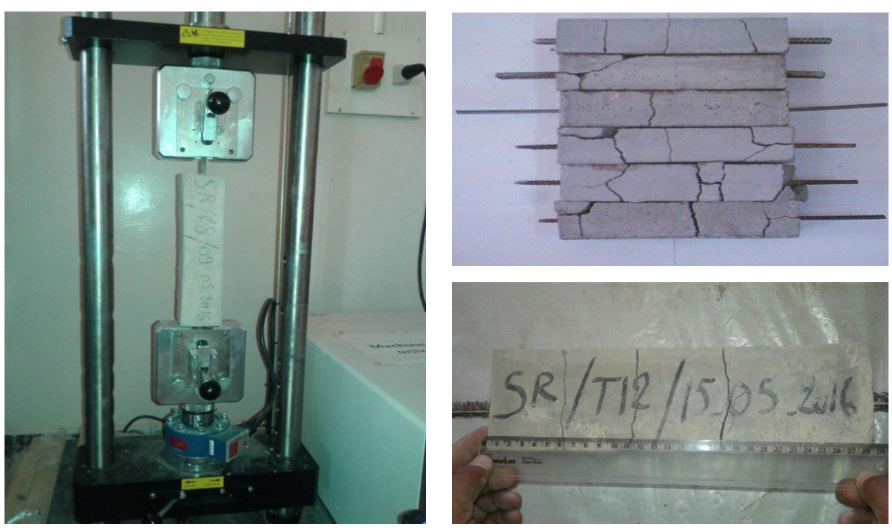
2.3. Experimental characterization procedure

The pulling specimen taken here to study the crack spacing, is a simulation of the cracked part of any beam between its two supports, the main reinforcement is therefore at the low level of the beam, where the concrete also is stressed by traction which by reaching its limit of tensile strength will crack in this area.

The specimen has the dimension (7x7x28 cm3) in concrete prism, of reinforcement coated in this prism having a total length of 40 cm, because with the 6 cm of steel extended beyond the longitudinal end of the prisms, have to hold the test piece at press level during the tensile test (fig.2). The specimen is held by its two symmetrical steel ends, to calibrate the tensile load.

The loading is carried out by an automatic piloting of the press (fig.2) with a low loading speed; corresponding to the same speed of the concrete compression test. The test piece in this test was stressed until the steel bar broke, reading the crack spacing is easily acquired on the crack network. The completion of the test was started at the time of the plasticity of the steel, where the crack network is already stabilized and the recovery of the tensile load is almost entirely taken up by the reinforcement.

The measurement of the spacing of the consecutive cracks is carried out after stability of the network of cracks it can be evaluated on the four lateral faces of the test-tube. The distance between the free edge and the first crack is not taken into account, because the edge effects introduced by the free surface completely modify the value of this spacing (fig. 2)



a) (c)

Figure.2 (a) Universal testing machine device assembly of test pieces after test (b) network of cracks. (c) measurement of crack spacing)

3. Experimental results and analyzes

The measurement of the total elongation of the tie rod was exploited as the traction loading was carried out by the simultaneous recording of the overall elongation of the test specimen with the increase in the load. To this end, the experimental results are shown in Figure 3.

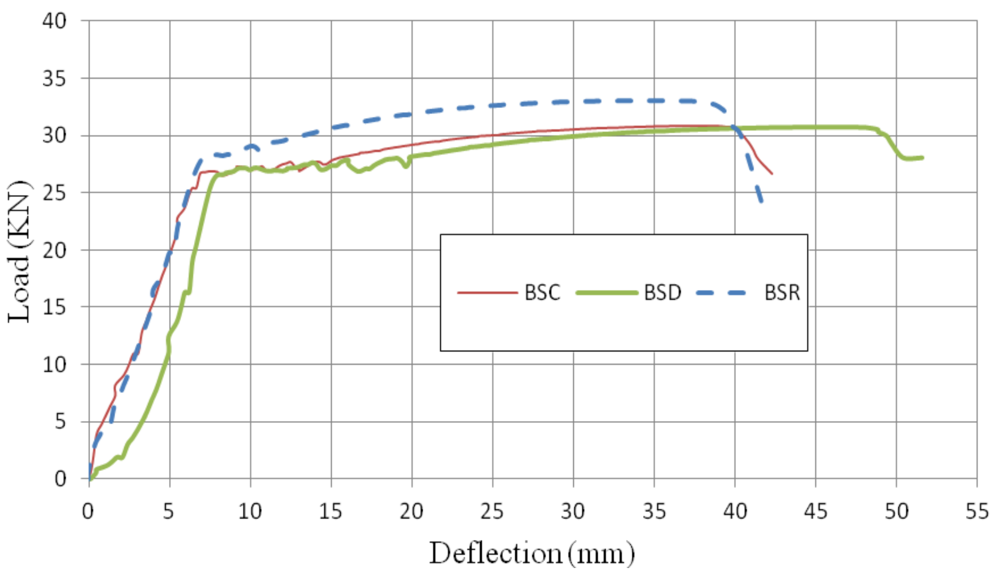


Figure 3 Extension of the Ø8 tie rod under tensile stress
«Case of three types of sand BSC; BSD; BSR »

From this figure, we can observe that the evolution of the overall deformation of the pulling specimen begins at the beginning with an almost linear behavior (elastic phase). Thus, the behavior of the tie rod goes through several symptomatic phases [9,11,12].

a) **Non-cracked phase**: In this phase the element behaves in a pseudo-linear elastic homogeneous fashion and does not crack, as long as the concrete has not yet reached its tensile strength. The appearance of the first crack corresponding to the tensile strength of the concrete.
b) **Crack formation phase**: this phase is mentioned by a gradual decrease in the rigidity of the element as new successive cracks appear and by the low rate of increase in normal force.
c) **Stabilized cracking phase**: In this last phase, the normal force increases more sharply than before, and no new crack develops. This phase will result in the rupture of the element where the relative elongation of the reinforcement exceeds the value corresponding to the flow limit of the steel used.

In order to determine the influence of the diameter of the bars on the cracking, we gathered on (figure 4) the evolution of nominal diameter of the bars (HA8, HA10, HA12 and HA14) according to the average spacing of the cracks for the three elaborate sand concretes.

From this figure, we can mainly observe that all the spacings are reduced with the increase in the diameter of the bars, only the diameter (HA14) presents a very strong increase for the three concretes. this is mainly linked to the diametral pressure which causes the encasing concrete to burst and largely detach it from the reinforcement, otherwise the three types of concrete are refined in spacing value, especially when it acts of (HA10 and HA12).

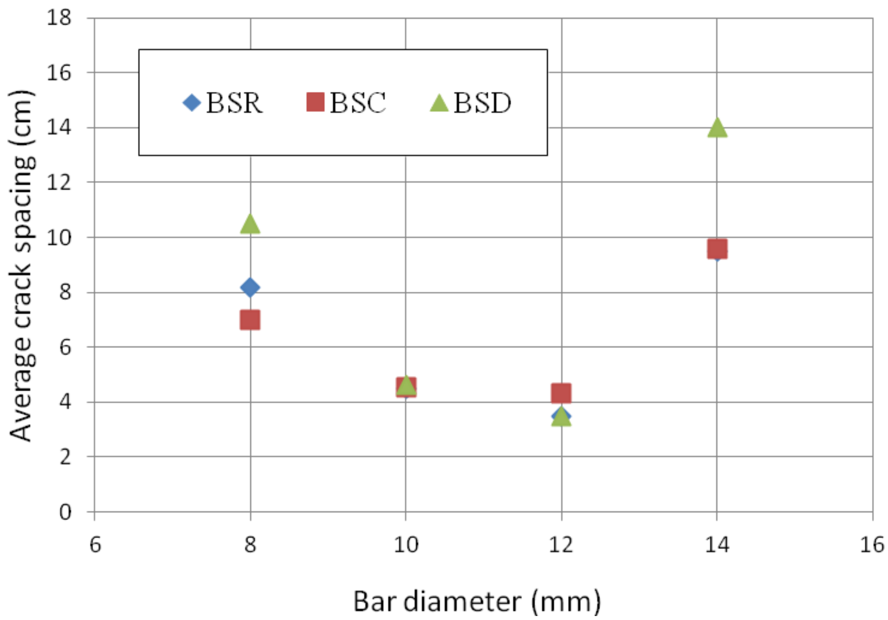


Figure 4 Influence of diameter on the mean crack spacing.

To determine the influence of the geometric percentage of reinforcement, we grouped the variations of the average crack spacing according to the percentage of reinforcements used, for the different types of sand concrete used, on figure 5 ci below. From this last, we can note that the increase in the geometrical percentage of reinforcements in the section involves a reduction in the average spacing between the cracks except in the case (HA14) of strong percentge (ρ = 0,03%), which confirms that the concrete resistance has only a very weak influence on the cracking network especially for the tie rods of average diameter (Ø10 and Ø12 mm).

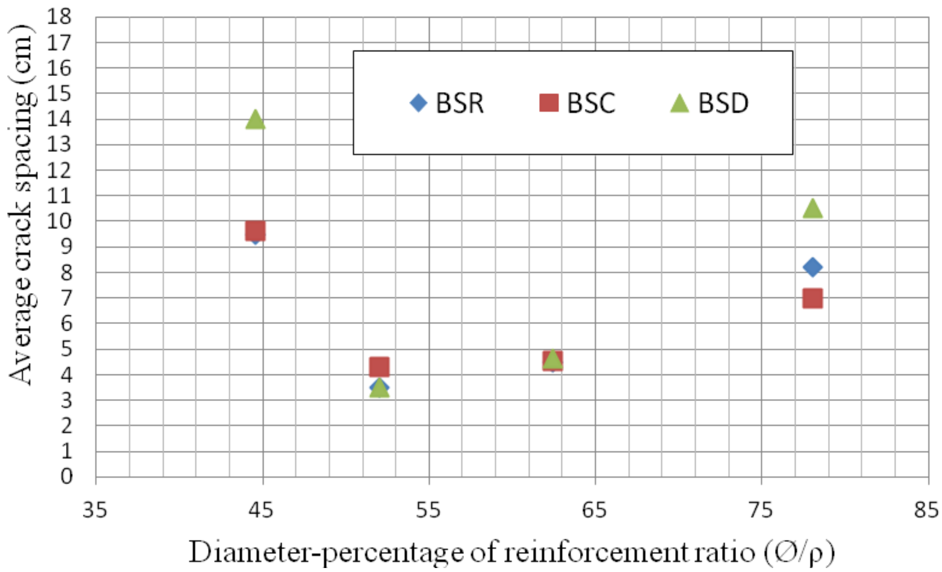


Figure 5 Influence of the diameter-percentage ratio of reinforcements (Ø / ρ)

5. Conclusions

The experimental set-up reserved for the test having successfully completed the task intended for the study of crack spacing, we carried out for this purpose compositions of sand concrete making it possible to concretize the crack spacing parameter. These tests carried out in this experimental program were followed by a simultaneous recording of the total elongation of the tie as a function of the tensile load, which also makes it possible to detect the appearance of cracks and the corresponding loads. Analysis of the experimental results allows us to draw the following conclusions:

- ✓ Increasing the reinforcement rate in the section reduces the average crack spacing.
- ✓ The variation of the different types of sand concrete has little influence on the crack behavior of the tie rod because the spacings obtained after the network stability merge for the different types of concrete.
- ✓ The effect of diametrical pressure only has an effect from reinforcement diameters exceeding 14 mm, otherwise the spacing of the cracks, in terms of growth, corresponds to the inverse of the diameter [13].
- ✓ This study made it possible to open up very broad perspectives for the use of sand concrete, as much as reinforced concrete, still remains the elaboration of studies concerning the main elements made of sand concrete.

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