# The Effect of Adding Crushed Sand on the Mechanical Performance of Concrete Used in Aggressive Environments in the Region of Touggourt

**Tobchi Mohamed Bachir [1,2], Kriker Abdelouahed [1,2], Belarbi Dalila[1,2]**

[1]Department of Civil Engineering and Hydraulics, Ouargla University,Algeria.

[2]Laboratory of Exploitation and Valorization of Natural Resources in Arid Zones,Ouargla University,Algeria.

**(Corresponding Author):*E-mail:** tobchi.med.bachir@univ-ouargla.dz

**Received:** 09-04-2023 **Accepted:** 24-07-2023 **Published:** 01-08-2023

**Abstract :**

The objective of This research is to study the influence of crushed sand on enhancing the mechanical performance of ordinary concrete with a class rating of (35/45) when exposed to aggressive environmental conditions, particularly in the presence of rising waters. To achieve this goal, we combined natural sand with crushed sand in the following proportions (0%, 40%, 45%, 50%, 55%, 60%, 100%). The experimental results show an improvement in the compressive, flexural, and tensile strength of the hardened concrete after 7 days, 28 days, and 90 days, especially with an optimal replacement rate of 50% crushed sand in comparison to natural sand.

**Keywords:** Cement, Concrete, Natural sand, River sand, Crushed sand, Mechanical strength, Aggressive environment.

**Tob Regul Sci. ™ 2023;9(1): 3768-3778**
**DOI: doi.org/10.18001/TRS.9.1.265**

## 1 Introduction:

The construction sector is one of the largest consumers of natural resources and energy in the world, with concrete being one of the primary construction materials used. The rapid increase in construction activities in recent years has led to a significant rise in the consumption of natural aggregates for concrete production to meet the requirements of durability and mechanical performance. Approximately 35 to 40% of the concrete volume consists of sand, a natural resource used in concrete production. However, excessive exploitation of natural sand has led to its depletion in Algeria. Halesh Kumar et al. estimated that replacing natural sand with manufactured sand induces higher strength in concrete than conventional concrete [1]. Several regions in our country are facing a shortage of good-quality natural sand. Therefore, it is necessary to explore alternatives to natural sand while ensuring the durability of concrete and

mortar is not compromised. Environmentalists also raise concerns about the extensive use of river sand, which has made natural sand very expensive and scarce in several regions [2]. In this regard, crushed sand is a good alternative to natural sand, but finding the optimal replacement percentage to achieve maximum compressive, tensile, and flexural strength with ordinary Portland cement is essential. Solving this problem becomes more crucial in the current situation. Crushed sand from rocks is the most economically and practically viable option. Its usage as a substitute for natural sand becomes necessary to meet the construction sector's needs and address storage problems. Therefore, it is necessary to examine these properties to determine the optimal substitution. Additionally, some natural sands lack fine particles necessary for reducing concrete porosity and ensuring granular continuity between cement and gravel [3]. Thus, it is preferable to use sand with a spread-out grain size and well-distributed grain diameters for concrete production [4]. Despite the increasing number of quarry sites producing a large quantity of crushed sand in the southwest of Algeria, it is not being used as an alternative to natural sand in concrete construction. However, very few scientific recommendations are available for the use of crushed sand in Algeria. The general objective of this research, as part of the valorization of local materials, is to study the influence of crushed sand on improving the mechanical properties of concrete exposed to rising waters from an agricultural trench in the region of the region of Touggourt, Algeria, where the water has moderate aggressiveness.

## 2 Materials Used:

### 2-1 Cement:

The cement used in this study is a CRS CEM I 42.5 R/SR5 produced by GICA-Algeria, complying with the Algerian standard NA 442, 2003 [5], and the European standard NF EN 197-1 [6]. Its physical and chemical characteristics are illustrated in Tables 01 and 02.

### 2-2 Admixtures:

An admixture was used during our study; it is a high-range water-reducing superplasticizer manufactured by the company Granitex and marketed under the name "MEDAFLOW 145." According to the technical data sheet, it is based on polycarboxylate ethers, in liquid form, light brown in color, and contains 30% dry extract. Its density is 1.065±0.015, pH ranges from 5 to 6, and the chlorine content is less than 1 g/l. The recommended dosage range for MEDAFLOW 145 is 0.3% to 2% of the cement weight. This type of superplasticizer allows for reducing the Water/Cement (W/C) ratio while significantly improving the fluidity of the concrete. It also increases the mechanical strength both at early and long-term ages.

### 2-3 Aggregates:

In our study, we distinguished two types of sand: natural sand (SN) obtained from the KASEB ELSIL quarry (OUARGLA), and crushed sand (SC) obtained from the BENBRAHIM crusher quarry (HASSI MESSAOUD). Their particle size distribution curves are illustrated in Figure 01. We conducted mixtures of construction-grade natural sand with crushed sand from the quarry, with percentages of 0% SC, 40% SC, 45% SC, 50% SC, 55% SC, 60% SC, and 100% SC. The

particle size distribution curves for mixtures from 40% to 60% are shown in Figure 02. The value of methylene blue for the natural sand used is 0.1 (ml/g). The chemical analysis values of the aggregates used are expressed in Table 03. The (SN) has a distribution ranging from 0.08 to 5 mm, with a fraction of grains smaller than 0.08 comprising approximately 3% (see Figure 01). The gravel used in our study was supplied from the BENBRAHIM quarry (HASSI MESSAOUD). Two fractions of gravel were used in our study: 8/15 and 3/8, as shown in Figure 03. The physical characteristics of the aggregates are presented in Table 04. The grains of natural sand have a rounded shape, while the grains of crushed sand have an angular shape. Additionally, the fineness modulus of the natural sand is 2.22, and for the crushed sand, it is 2.18, indicating that the crushed sand used is finer than the natural sand.

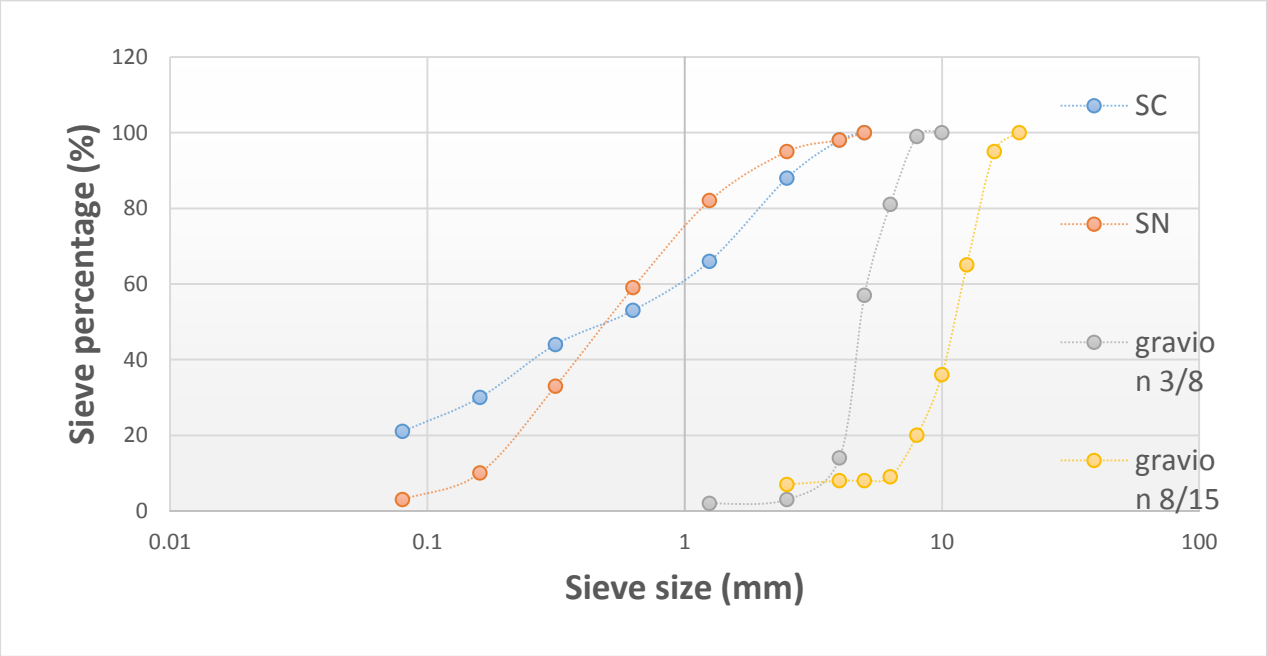


**Figure 1: Particle Size Distribution Curve of the Aggregates Used.**

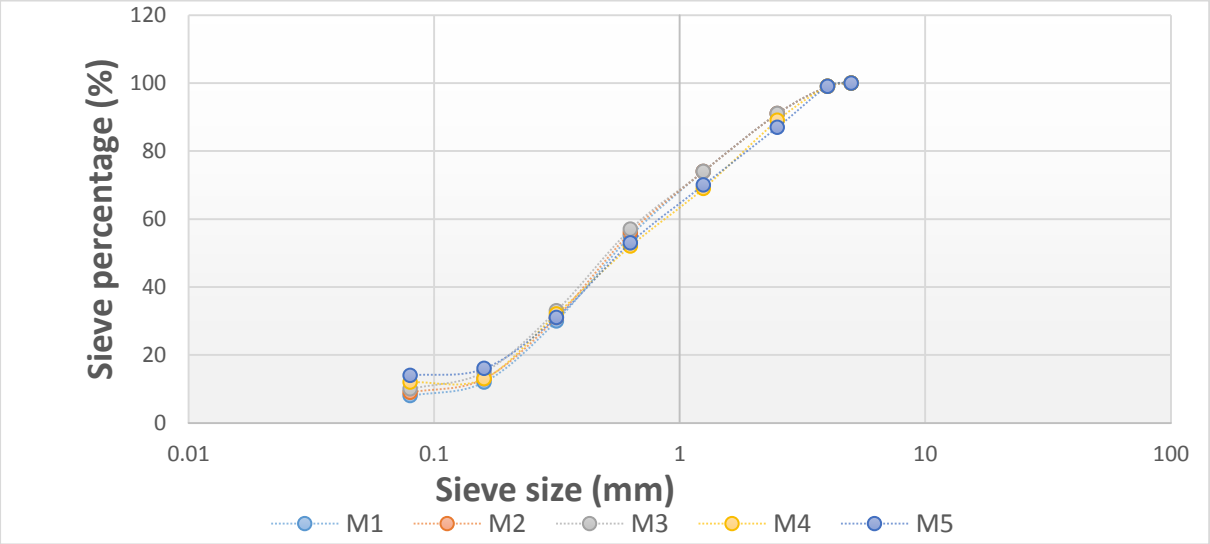


**Figure 2: Particle Size Distribution Curves of the Sand Mixtures.**


**Figure 03:Used Gravels**

**Table 01: Physical Characteristics of CRS Cement**

| $SIO_2$ | $AL_2O_3$ | $Fe_2O_3$ | CaO | MgO | $K_2O$ | $Na_2o$ | $SO_3$ | $CL^-$ | P.A.F | CaO Libre |
|---|---|---|---|---|---|---|---|---|---|---|
| 21,03 | 4,47 | 4,18 | 61,03 | 1,57 | 0,69 | 0,13 | 2,27 | 0,0176 | 1,19 | 0,82 |

**Table 02: Chemical Compositions of CRS Cement.**

| P.S ($g/cm^3$) | S.S.B ($cm^2/g$) | Consistency (%) | Beginning of setting (min) | End of setting (min) |
|---|---|---|---|---|
| 3,15 | 3835 | 25,41 | 139 | 208,6 |

**Table 03: Chemical Analysis of the Used Aggregates.**

| *Paramètres* | *CaCo3 (%)* | *Insoluble (%)* | *$Cl^-$ ( %)* | *$CaSO_4 2H2O$ (%)* | *$So_3^-$ (%)* | *$So_4^-$ (mg/l)* |
|---|---|---|---|---|---|---|
| *Sn* | 1,97 | 96,03 | 0,014 | 0,61 | 0,28 | 33,75 |
| *G 3/8* | 59,39 | 29,39 | 0,028 | 3,80 | 1,76 | 211,54 |
| *G 8/15* | 49,77 | 29,20 | 0,023 | 3,06 | 1,42 | 170,38 |

| **Physical characteristics** | SN | SC | G 3/8 | G 8/15 |
|---|---|---|---|---|
| Specific density (g/cm3) | 2,601 | 2,66 | 2,61 | 2,61 |
| Apparent density (g/cm3) | 1,61 | 1,48 | 1,26 | 1,29 |
| Fineness modulus | 2,22 | 2,18 | / | / |

| | | | | |
|---|---|---|---|---|
| Sand equivalent | 62,25 | 78,35 | / | / |
| Flakiness index (%) | / | / | 29 | 20 |
| L.a (los angles) | / | / | 28 | 28 |
| Absorption (%) | / | / | 1,74 | 1,54 |
| Surface properties (%) | | | 2,30 | 1,87 |

**Table 04: Physico-Mechanical Characteristics of the Aggregates.**

## 3 Experimental Methods:

### 3-1 Preparation and Production:

The method employed for formulating the concrete is the Dreux Gorisse method [7], and the composition used is that of ordinary concrete with a class rating of C(35/45). Seven concrete mixtures, labeled M0, M1, M2, M3, M4, M5, and M6, are prepared with different percentages of crushed sand (SC) substitution, namely (0%, 40%, 45%, 50%, 55%, 60%, 100%). It is important to note that M0 serves as the control group. The Water/Cement ratio (E/C) is fixed at 0.42, and the cement dosage used is 450 Kg/m³. The various proportions of the materials used are indicated in Table (05).

**Table 05: Proportions of Materials Used in Concrete Mix (Relative to the Weight of Cement).**

| *Type of concrete* | *Cement* | *SN%* | *SC%* | *G1(3/8)%* | *G2(8/15)%* | *Admixture (%)* |
|---|---|---|---|---|---|---|
| *MO* | 1 | 1,493 | 00 | 0,271 | 2,135 | 1% |
| *M1* | 1 | 0,929 | 0,619 | 0,231 | 2,135 | 1% |
| *M2* | 1 | 0,851 | 0,697 | 0,231 | 2,135 | 1% |
| *M3* | 1 | 0,771 | 0,771 | 0,231 | 2,135 | 1% |
| *M4* | 1 | 0,716 | 0,875 | 0,231 | 2,095 | 1% |
| *M5* | 1 | 0,637 | 0,956 | 0,231 | 2,095 | 1% |
| *M6* | 1 | 00 | 1,526 | 0,271 | 2,135 | 1% |

### 3-2 Preparation of Test Specimens:

The concrete test specimens were prepared as follows: cubic specimens measuring 150x150x150 for compression testing, prismatic specimens measuring 100x100x400 for flexural testing, and

cylindrical specimens with diameter D/110 and height H/220 for tensile testing (Brazilian test). The study was conducted on samples at 7 days, 28 days, and 90 days. The material was poured in two layers with 25 shocks to eliminate air bubbles [8].

### 3-3 Conservation of Test Specimens:

After the preparation of the test specimens, they are stored in an agricultural drainage trench in Touggourt, Algeria (Figure 05). It was observed that the water in this environment has a moderate chemical aggressiveness [9]. The physico-chemical compositions of these waters are illustrated in Table 06.

**Table 06: Physico-chemical analysis of aggressive environment.**

| PH | R.S(mg/l) | $Ca^{+2}$(mg/l) | $Mg^{+2}$(mg/l) | $cl^{-}$(mg/l) | $So_4^{-2}$(mg/l) | $No_3^{-}$(mg/l) | $Na^{+}$(mg/l) | $k^{+}$(mg/l) |
|---|---|---|---|---|---|---|---|---|
| 7,9 | 7296 | 250 | 465,9 | 2008,5 | 2400 | 1,2 | 1117,5 | 47,5 |

**Figure 04: Sampling of Concrete Test Specimens.**

**Figure05:Conservation of Test Specimens in an Aggressive Environment (Agricultural Trench).**

## 4 Results Obtained And Discussion:

### 4-1 Compressive Strength:

The results of the compressive strength (Rc) of the concrete mixtures are illustrated in Figure 05 . It is observed that the mixture M3 with 50% crushed sand (SC) and 50% natural sand (SN) exhibits the highest compressive strength. These results have been confirmed by several researchers. S. Mundra et al. observed a significant reduction in compressive strength at over 50% replacement of crushed sand [10]. Priyanka et al. confirmed that replacing 50% of natural sand with artificial sand in the mortar mixture results in higher compressive strength with a W/C ratio of 0.5 [11]. M.Adams.J et al. stated that replacing 50% of natural sand with crushed sand in concrete leads to better compressive strength [12]. The mixture M3 with 50% SC has a fines content of 10%, a result also observed by I. Joudi , in their study on the influence of crushed sands, showing that concrete without fines exhibits lower compressive strength compared to concrete with 12% fines [13]. Figure 05 shows that all the mixtures from M0 to M6 have increasing compressive strength, especially at 50% SC. This result has been confirmed by T. Djedid et al., who found that the presence of crushed sand improves the compressive strength of concrete exposed to rising groundwater for all substitution percentages of crushed sand, especially at 50% SC [14]. However, Figure 06 indicates a decrease in compressive strength for the M6 mixture designed with entirely crushed sand, which contains a fines content of 21% smaller than 0.08mm as represented in the particle size analysis in Figure 01. These results were also confirmed by Menadi et al., who showed a decrease in mechanical properties when the fines content reaches 15% [15]. This could be explained by the insufficient cement paste to cover all fine aggregate particles in the cement matrix [16].

### 4-2 Flexural Strength:

The results shown in Figure 07 demonstrate that the M3 mixture with 50% crushed sand (SC) achieves the highest flexural strength at all ages, recording a percentage increase of 26.57% and 44.63% at 28 days and 90 days, respectively, compared to the control mixture M0 with 0% SC. Additionally, it is observed that all mixtures containing natural sand and crushed sand exhibit increasing flexural strength. These results have been confirmed by T. Djedid et al., who also indicated that the flexural strength of concrete with limestone aggregates is better than that of concrete with natural sand [14]. Ahn, in 2000, demonstrated that certain characteristics such as higher micro fines, particle shape, and texture improve the flexural capacity of concrete compared to that of concrete with natural sand [17]. Abou-Zeid et al. reported that mixtures containing micro-fines had higher flexural strength compared to mixtures of concrete without micro-fines [18].

### 4-3 Tensile Strength:

The results obtained are illustrated in Figure 08 , showing an increase in the tensile strength of the M3 mixture with 50% crushed sand (SC) by 13,06% at 28 days and 12.09% at 90 days. R.

P. Mogre et al. observed that replacing 60% to 80% of natural sand with artificial sand is feasible for concrete quality, with a percentage increase of 5.39% in tensile strength when replacing natural sand [19]. L. Zeghichi et al. demonstrated that, unlike the rheological properties of fresh Self-Compacting Concrete (SCC), crushed sand contributed to the development of strength, especially in the case of tensile strength [3].

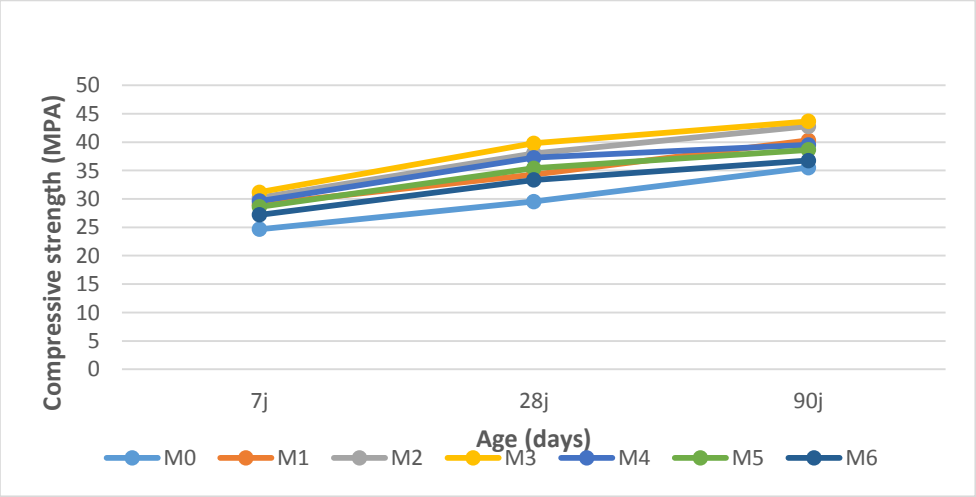


**Figure 05: Compressive Strength of Concretes Stored in an Aggressive Environment.**

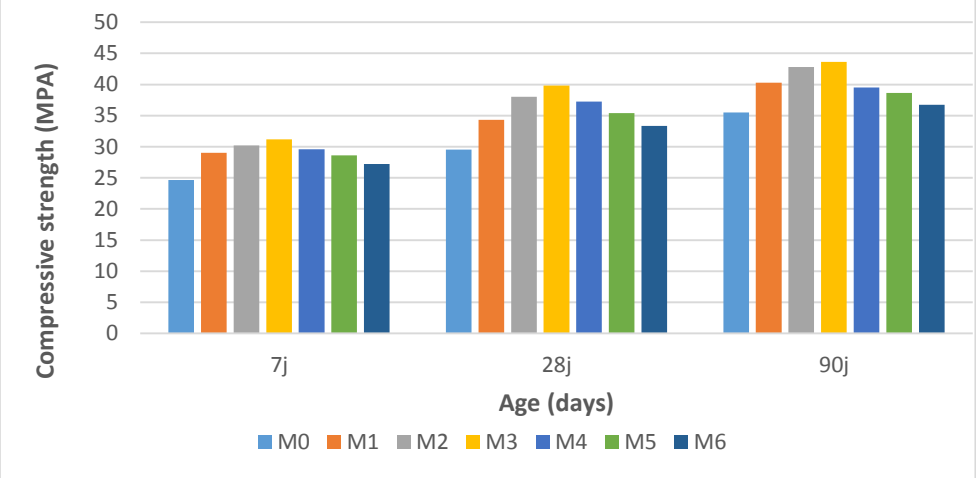


**Figure 06: Evolution of Compressive Strength of Concretes Stored in an Aggressive Environment.**

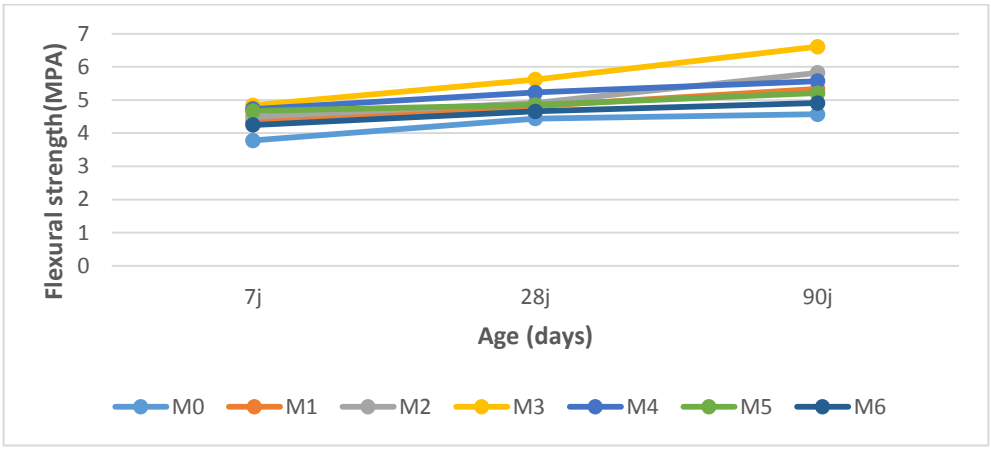


**Figure 07: Flexural Strength of Concretes Stored in an Aggressive Environment.**

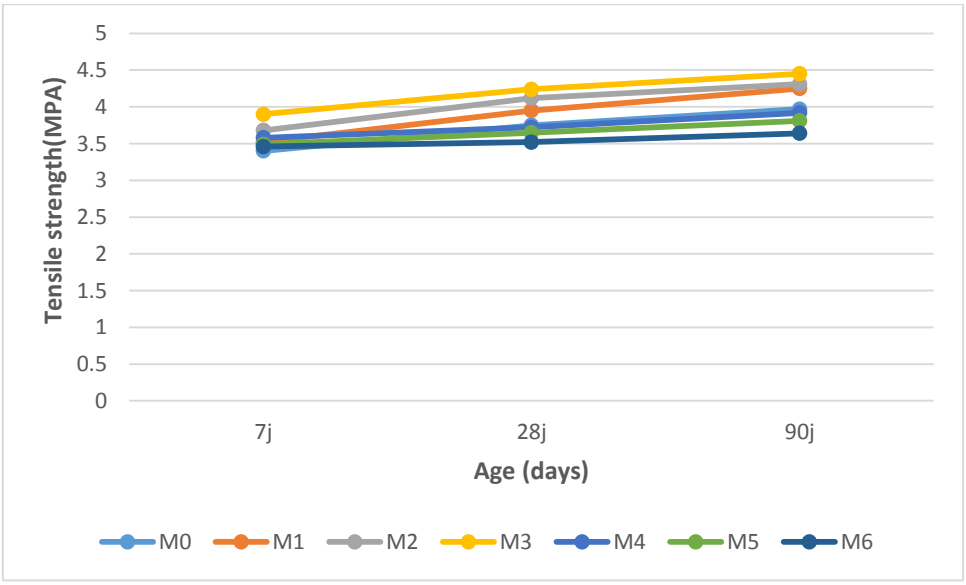


**Figure 08: Tensile Strength of Concretes Stored in an Aggressive Environment.**

## 5 Conclusion:

After this experimental work, we can confirm the following set of results:

a- Replacing 50% of natural sand with crushed sand in ordinary concrete increases the flexural strength of the concrete by 26.57% at 28 days and 44.63% at 90 days.

b- The optimal percentage of substitution of natural sand with crushed sand is 50%, which contains 10% of fines smaller than 0.08mm.

c- There is an increase in the tensile strength of the M3 mixture with 50% crushed sand by 13.06% at 28 days and 12.09% at 90 days.

d- In rising groundwater from an aggressive environment, when crushed sand is added at 50% to natural sand, the compressive strength increases by 34.73% at 28 days and by 22.95% at 90 days.

e- Crushed sand is beneficial for improving the mechanical characteristics of concrete stored in an aggressive environment.

**References:**

[1] A. H. Halesh Kumar and S. Bhargavi, "Replacement of Fine Aggregate by M-Sand," *Int. Journal of Science Technology &*Engineering, vol. 3, pp. 223-227, 2017.

[2] S. George, J. John, P. Magudeswaran, and R. Thenmozhi, "Replacement of river sand using manufactured sand and quarry dust in cement concrete," *Nature Environment and Pollution Technology,* vol. 7, pp. 475-478, 2008.

[3] L. Zeghichi, Z. Benghazi, and L. Baali, "The effect of the kind of sands and additions on the mechanical behaviour of SCC," *Physics Procedia,* vol. 55, pp. 485-492, 2014.

[4] K. KOFFI, I. K. KOUAMÉ, E. K. KOUADIO, and A. G. DOUAGUI, "Étude des propriétés hydriques (porosité et conductivité hydraulique saturée) de l'aquifère du quaternaire d'Abidjan (Côte d'Ivoire)," *International Journal of Innovation and Applied Studies,* vol. 3, pp. 151-159, 2013.

[5] N. AS, "442," *Algerian Standard, Cement: Composition, specifications and conformity criteria for common cements, IANOR Algiers,* 2003.

[6] N. EN, "197–1-Ciment—Partie 1: composition, spécifications et critères de conformité des ciments courants," *AFNOR, Paris,* 2001.

[7] G. Dreux and J. Festa, *Nouveau guide du béton et de ses constituants*: Eyrolles, 1998.

[8] N. EN, "12390-2. Essais pour béton durci-Partie 2: confection et conservation des éprouvettes pour essais de résistance," ed: Octobre, 2001.

[9] N. EN, "206-1 Béton—Partie 1: Spécification, performances, production et conformité," *AFNOR, French standard, from European standard EN,* vol. 206, 2004.

[10] S. Mundra, P. Sindhi, V. Chandwani, R. Nagar, and V. Agrawal, "Crushed rock sand–An economical and ecological alternative to natural sand to optimize concrete mix," *Perspectives in Science,* vol. 8, pp. 345-347, 2016.

[11] P. A. Jadhav and D. K. Kulkarni, "Effect of replacement of natural sand by manufactured sand on the properties of cement mortar," *International journal of civil and structural Engineering,* vol. 3, p. 621, 2013.

[12] M. A. Joe, A. M. Rajesh, P. Brightson, and M. P. Anand, "Experimental investigation on the effect of M-sand in high performance concrete," *Am J Eng Res,* vol. 2, pp. 46-51, 2013.

[13] H. Hassis, L. Courard, N. B. Jamaa, M. B. Ouezdou, A. Lecomte, I. Kallel-Kamoun, and A. Beddey, "Influence des sables fillérisés calcaires sur les propriétés des bétons courants et superplastifiés. Un exemple tunisien," 2012.

[14] T. Djedid, A. Guettala, and M. Mani, "Study of the workability and mechanical strength of concrete in the face of upwelling (Case of the El Oued Region of Algeria)," *Journal of Fundamental and Applied Sciences,* vol. 11, pp. 368-384, 2019.

[15] B. Menadi, S. Kenai, J. Khatib, and A. Aït-Mokhtar, "Strength and durability of concrete incorporating crushed limestone sand," *Construction and Building Materials,* vol. 23, pp. 625-633, 2009.

[16] T. Celik and K. Marar, "Effects of crushed stone dust on some properties of concrete," *Cement and Concrete research,* vol. 26, pp. 1121-1130, 1996.
[17] N. Ahn, *An experimental study on the guidelines for using higher contents of aggregate micro fines in portland cement concrete*: The University of Texas at Austin, 2000.
[18] M. N. Abou-Zeid and M. M. Fakhry, "Short-term impact of high-aggregate fines content on concrete incorporating water-reducing admixtures," *Materials Journal,* vol. 100, pp. 280-285, 2003.
[19] R. P. Mogre, D. D. K. Parbat, and D. S. P. Bajad, "feasibility of artificial Sand in concrete," *International Journal of Engineering Research & Technology,* vol. 2, pp. 1606-1610, 2013