Revue des Composites et des Matériaux Avancés-Journal of Composite and Advanced Materials
Vol. 32, No. 2, April, 2022, pp. 85-90
Journal homepage: http://iieta.org/journals/rcma

Combined Impact of Replacing Dune Sand with Glass Sand and Metal Fibers on Mortar Properties

Nadia Tebbal[1], Mekki Maza[2], Salim Zitouni[2], Zine El Abidine Rahmouni[2*]

[1] Institute of Urban Techniques and Management, Msila University, M'sila 28000, Algeria
[2] Laboratory for Geo-Materials Development, Civil Engineering Department, Faculty of Technology, Msila University, M'sila 28000, Algeria

Corresponding Author Email: zineelabidine.rahmouni@univ-msila.dz

https://doi.org/10.18280/rcma.320205

Received: 15 February 2022
Accepted: 8 April 2022

Keywords:
metal fibers, glass powder, air-entraining agent, mechanical behavior, mortar

ABSTRACT

This paper presents an experimental study on the influence of metal fibers on the mechanical behaviour of mortar with glass sand. Four mortar mixtures with glass filler and metals fibers are manufactured. The specimens were prepared with three percentages of glass sand (0%, 5%, 10%) and 1%, 2% by vol of steel fibers. The Air-Entraining Agent (A-E-A) dosages at the ratios of 0.08% of cement weight were used. The mechanical tests were carried out on the specimens such as the compressive strength, the tensile strength and the porosity. The results showed that the tensile and bending properties of all different mixtures with fibers are significantly higher compared to the reference mortars. A remarkable decrease has been observed in water, density and compressive strength of mortar with chemical admixture. Moreover, the using 1% volume fraction of steel fibers and 10% glass sand, flexural strength of mortar was completely improved.

1. INTRODUCTION

Concrete has diverse characteristics that make it widely acceptable for use worldwide; despite its many benefits, it has many drawbacks, that is, it is fragile in nature and its production causes a negative impact on the environment. In order to reduce these problems, sustainable measures have been introduced by researchers all over the world. The addition of fibers is considered one of the most important of these solutions because it prevents the spread of cracks and increases the overall strength of concrete. In the current age, civil engineering structures have their own structural and durability requirements and so, it has necessity to modify conventional concrete [1].

All researchers around the world confirmed that the use of steel fibers (SF) in concrete had very acceptable results with improvement of both tensile strength and modulus of elasticity [1, 2]. Fiber reinforced concrete (FRC), a cement-concrete reinforced with many small fibers which are distributed randomly in the concrete during mixing, ameliorated concrete properties in all directions [3]. While more new applications were identified a wide range of fibers was introduced, which include: steel fibers, glass fibers, carbon fibers, natural organic fibers and polypropylene fibers.

Generally, fibers are mainly classified according to their origin. Many researches have been conducted on natural and synthetic fibers separately to clarify their effect on various properties of concrete. A wide range of natural and artificial fibers have been utilized in FRC, but the use of steel fibers has significantly increased in the construction of industrial pavements, roads, parking areas and airports over the past two decades due to it is diffused fiber it may help in improving the structural behavior [4].

The use of natural fibers in concrete is recommended since several types of these fibers are available locally and are plentiful. The idea of using such fibers to improve the strength and durability of brittle materials is not new; for example, straw and horsehair are used to make bricks and plaster. Natural fibers are suitable for reinforcing concrete and are easily available in developing countries [5].

The various results proved that the types of fibers and their percentage in concrete have a different role in the rheological and mechanical properties of concrete. For all natural and artificial fibers types of fibre optimum percentage of fibers was 2.5% considering the sufficient improve of all properties [6].

Islam et al. showed that steel fibers exhibit maximum efficiency in enhancing compressive and bending strength and also impart higher ductility, followed by synthetic fibers in terms of effect. The role of natural fibers is very low in improving compressive strength, but its effect is moderate when subjected under flexure [7]. The conclusion of the study was that the fibres play a great role with its combining effect on the post cracking ductility and energy absorption of concrete.

Furthermore, statistics on pollution stated that cement is one of the main contributors to dangerous greenhouse gases, especially carbon dioxide [8], which is estimated at ten percent of global carbon dioxide emissions [9]. Hence, it was necessary to think about meeting the sustainable development goals for the environment by reducing the use of cement, in order to obten the necessary strength or to maintain the targeted strength, the employement of other more sustainable methods than to use cement in excessive quantities can be preferable. This practice is feasible as well as eco-friendly. Among all the techniques used to meet this need, the addition of cement materials and fibers is notable and distinctive [10]. For this purpose, differente materials has been added such as granulated slag, metakaolin fly ash, etc. with (SF) to obtain a strong and durable concrete with the precise proportioning, mixing and compacting of ingredients [11].

Ahmed et al. [12] reported that the workability of mixed concrete decreases with increasing fiber content. Nitin Verma et al. [13] afirmed that the strength of concrete with fiber was very higher than the reference concrete.

The results obtained by Belouadah et al. [14, 15] indicated that 10% replacement level of glass powder (GP) with cement exhibited the best performance of concrete. Yasouj and Ghaderi [16] observed that 20% GP mix incorporated with 0.2% basalt fiber (BF) and 0.1% carbon nanotube (CNT) exhibited higher mechanical properties.

Koksal et al. revealed that combined use of 0.75 % micro-steel (MS) and 3% basalt fibers (BF) achieved the highest compressive strength of 64.4 MPa which was 62.21 % higher than control mixtures at 20 % SF content. Also, the mixtures containing 0.3 % BF exhibited the highest compressive strength [17].

Based on the results of Mário dos Santos Periquito et al. [18], the use of crushed stone sand in steel fiber reinforced concrete is beneficial in terms of the workability and abrasion resistance but was some disadvantages. Recent research has shown that the cracking and age stress of concrete vary with the rate of mineral additions and fiber content [19]. This study demonstrated that the percentages 1% and 2% of metal fibers play an important role in the concrete to sew the microcracks and limit the formation of other cracks by reinforcing the cementitious matrix, and by preventing the enlargement of the cracks.

Mahesh et al. reveal the reinforcing jute with natural rubber enhances the tensile strength compared to natural rubber sheet and the wear of the proposed flexible composite is minimal due to inclusion of natural rubber which is elastic in nature [20]. The weight percentage of fiber and rubber used in this study were 30% and 70% respectively.

Sangeetha in her study showed that different combinations of admixtures increases the compressive strength [21]. Rahma et al. presented the best results of concrete formulated with the substitutions of glass powder and plasticizer [22]. Chadli et al. [23] reported that the the mechanical strength of concrete formulated with 0.23% volume fraction of steel fibers, 15% slag and 23% quartz powder showed the maximum best mechanical performance.

In concrete or mortar, metallic fibers and waste glass have generally been used with super plasticizers to improve its performance. Insufficient experimental attempts have been made to study waste glass, metal fibers with air entrainment agent in concrete or mortar. Thus, this study aims to evaluate the properties of mortars to explore the possibilities to improving the performance of mortar formulated with metallic fibers, waste glass and air entrained agent for use in building products and its various applications.

Through this study, we have prepared and evaluated the performance characteristics of mortar reinforced with fiber and optimal replacement of cement by glass.

2. EXPERIMENTAL AND MATERIALS USED

This section presents the materials properties which are used in the study; this material include cement, fine aggregate (sand) and waste glass sand which is used as mineral or supplementary materials.

Cement Portland (CEMII 42.5) was used in this study. It has a density of 3.2 and Blaine specific surface area of 3850 cm^2/ g.

The dune sand with particles ranging from 0.08 mm to 5 mm in size was taken from Boussâada region (Algeria). The sieve analysis is according to the Eurepean standard (NF EN 933-1) [24].

The waste flat glass (WG) was obtained from the glass wastes of glass bottles, which are crushed and ground for 0.5 h in a ball mill after being cleaned and dried (see Figure 1).

Table 1 shows the chemical properties of GP and cement used.

The steel fibers (SF): used are cold-drawn steel fiber product manufactured by the company GRANITEX (Algeria). These fibers, which have a wavy shape, are 50 mm long and 2 mm wide with a diameter equal to 1.05 mm (Figure 2). In this paper, two proportions of steel (1% and 2% by volume) were used.

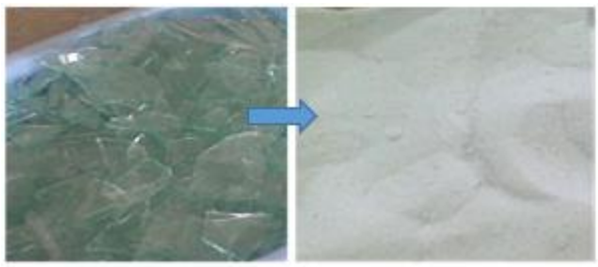

Figure 1. Waste glass sand after sieving in 0.08mm sieve

Table 1. Mineralogical and chemical and characteristic of cement, waste glass (WG) and dune sand (DS)

Chemical characteristics (%)								
	S_iO_2	CaO	Al_2O_3	Fe_2O_3	MgO	SO_3	Na_2O	K_2O
Cement	17.8	61.2	4.4	2.6	1.8	2.6	0.1	0.6
Glass	72.84	9.66	0.98	0.55	1.76	0.25	12.69	0.43
Dune sand	88.25	2.94	00.71	00.96	**00.17**	**00.08**	00.01	00.30
Mineralogical characteristics **(%)**								
C_3S		C_2S		C_3A			C_4AF	Gypse
45.8		14.3		2.6			10	19.8
Characteristics of air entraining agent **(**MEDA - AIR**)**								
Nature		PH		Density			Ions chlores	
Liquid		7 - 8		1± 0.01			≤ 1 %.	

Table 2. Mortar composition with glass powder

Mix	MC	M5G 0F	M10G 0F	M5G 1F	M5G 2F	M10G 1F	M10G 2F
AEA				0.36			
Cement	450	427.5	405	427.5	427.5	405	405
Sand dune				1350			
Water/Cement				0.50			
Glass powder	-	22.5	45	22.5	22.5	45	45
Fibers	-	-	-	4.5	9	4.5	9

MC: control mortar; M5G 0F: mortar with 5% glass powder and 0% fibers; M10G 0F: mortar with 10% glass powder and 0% fibers; M5G 1F**:** mortar with 5% glass powder and 1% fibers ; M5G 2F: mortar with 5% glass powder and 2% fibers ; **M10G 1F:** mortar with 10% glass powder and 1% fibers; M10G 2F: mortar with 10% glass powder and 2% fibers.

The adjuvant: is an air entraining agent (MEDA - AIR). The percentage used was 0.08% by weight of cement for all mixes formulated [25, 26].

A mortar mixer was used for the preparation of the test pieces with dimensions 40 mm x 40 mm x160 mm. Two pourcentages of glass waste powder (5%, 10% by weight of cement) were used; with 1% and 2% by vol. of steel fibers.

The fresh mortar mixtures were prepared using proportions of 1:3:0.5 by weight for cement, sand, and water respectively for all mixtures used in this study.The details of mortar mixtures which cured by water are shown in Table 2.

The compressive and bending tensile strength was tested according to NF-EN 196-1 [27]. The mortar specimens are preserved in their mould at a temperature 20°C with a humidity of 95% HR for 24 hours before demolding. Thereafter, they were kept under water till the age of testing. After 28 days, mechanical tests were carried out with a crushed specimen kept aside to examine the pore structure.

Porosity: The protocol of porosity accessible to water conforms to the recommendations of AFREM [28] group. The porosity test is carried out on test pieces of dimensions 4cm × 4cm ×16 cm, by applying the following steps:

- Dry the sample in an oven at 105°C for at least 24 h until a constant mass obtained. Then they were weighed once dry (A);
- Immersion of the sample in water for 24 hours;
- Heating to boiling for 5 hours, then weighing the sample in air (weight "C");
- Finally, hydrostatic weighing (D: weight of saturated samples subjected to Archi-medes).

The porosity was calculated by the formula:

$$P (\%) = [(C-A) /(C-D)].100 \qquad (1)$$

Figure 2. Metal fibers used

3. RESULTS AND DISCUSSION

3.1 Compressive strength

Figure 3 presented the compressive values for all hardened mortars.

A notable increase in the compressive strength is observed with the increasing in the percentage replacement of cement by GP from 0% to 10%. This rise can be seen by substituting the 10% which accompanied a 17% increase in compressive. Since the replacement of GP increases, mortar porosity decreases. However, the increase in strength occurred due to the pozzolan effect of powdered glass. This result can be explained by the role of GP acts as a pozzolanic material, the porosity reduced and the durability of mortar increase [29-31].

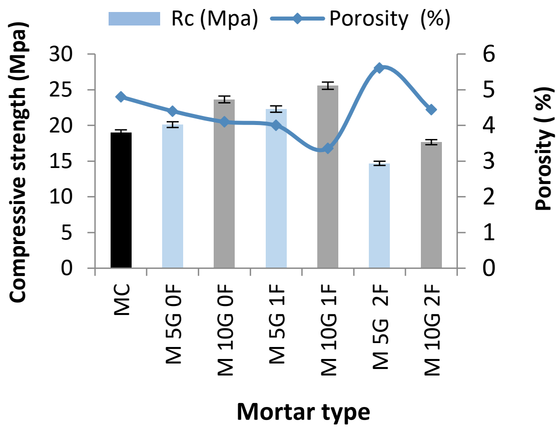

Figure 3. Compressive strength and the porosity of the different mortars

The porosity decreased with increasing of glass content and the lowest value was found for mortar formulated with 10% GP and 0% fiber (M10G 0F). This result was confirmed by Belouadah et al. [30, 32].

For the compressive strength of mortar with and without being reinforced with SF, it can be observed that with the increase in fiber content the compressive strength also increases.

The strength is gained continuously till 1% where the maximum strength is gained, which is 25.6% higher than the strength achieved by MC. The control mortar achieved 19 MPa, with addition of 1% steel fibers and 5 % G the mortar achieved 22.3 MPa and with1% steel fibers 10% G the mortar achieved 25.6 MPa. Further increase in steel fiber content to 2% has less strength of 14.7 MPa for M5G 2F and 17.7MPa for M10G 2F higher than the MC respectively. This decrease may be due to a higher content of fibers (2%) In which can lead to congestion of the fibers, resulting in a ball effect and a poor adhesion with the mortar.

3.2 Flexural strength

Figure 4 shows the result of flexural strength of mortar. it can be observed that the 1% steel fiber reinforced mortar achieved the highest flexural strength of 4.46 MP and 4.75

MPa compared to MC, M5G 0F and M10G 0F which achieved 2.75 MPa, 3MPa and 3.3MPa respectively.

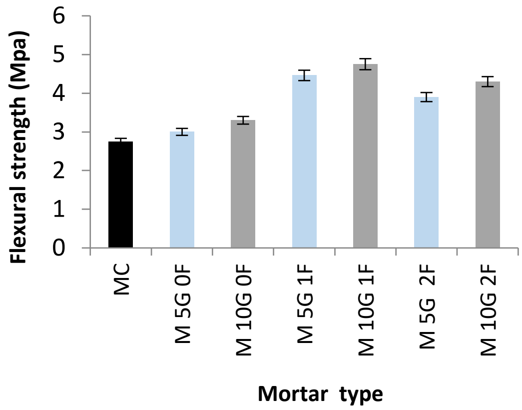

Figure 4. Flexural strength of mortars

Figure 5. Surface of mortar after flexural strength test

The increase in flexural strength of mortar with the increase in steel fiber reinforcement can be seen similar to that of compressive strength. The increase in flexural of mortar when reinforced with SF is due to the fact that as the fiber content in the mortar gradually increases, it greatly helps in restricting the formation, propagation and widening of cracks more effectively. Further increase in steel fiber reinforcement decreased flexural strength to 3.9 MPa and 4.3 MPa for 2% steel fibers respectively, though the flexural strength achieved by 2% steel fiber reinforcement in mortar was higher than the control mortar MC (see Figure 4). The increase in flexural strength of steel fiber reinforced mortar is due to the acceptable fiber content in the mortar, which greatly helps in reducing cracks and their subsequent propagation and expansion.

Figure 5 shows the efficiency of fibers in mortars. The flexibility behaviour of samples was observed in M 10G 1F and the effective linking action of fibers through the cracks. However, there is an upper limit of content steel fibers (1%) which can be used to reinforce. After this limit, the additional increase in the fiber content leads to the effect of balling and adhesion is inappropriate concreted, and as a result, the loss occurs in the bending strength.

3.3 Scanning electron microscopy

Figure 6 shows the Scanning Electron Microscopic (SEM) micrographs which present the microstructure of control mortar (a) and M10G 1F mortar (b) after 28 days of curing. The microstructure of mortar M10G 1F is very dense compared to the control mortar without fiber, and the SF are heavily bonded to the cementitious matrix. Moreover, the visual observations of the surface of the MC prove the growing cracks holes with an absence of fiber [23].

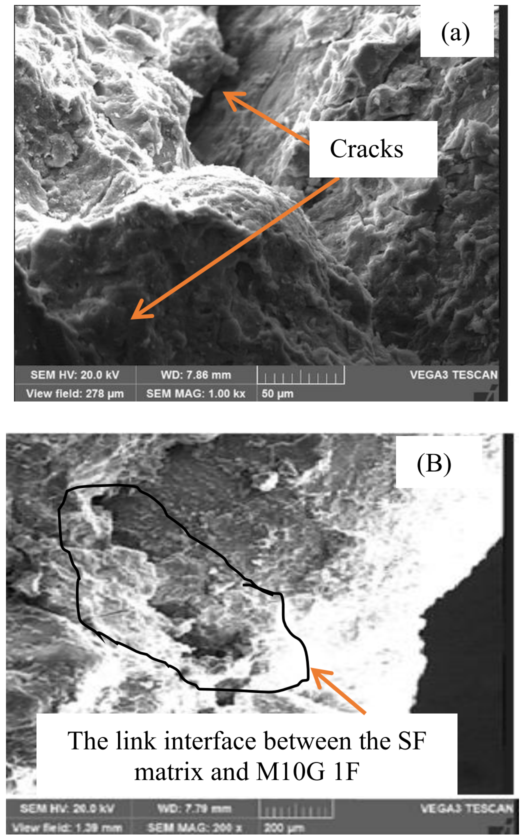

Figure 6. SEM of MC and M10G 1F mortars

4. CONCLUSION

In this study, the effect of metal fibers, glass sand on the mechanical behaviour of mortar was investigated. The results obtained can be summarized in the following points:

Waste glass powder is relatively a new supplementary cementing material which can be used in the mortar mixtures;

When using the GP as replacement by cement the compressive of mortar increased and the flexural increased too.

The maximum compressive strength of mortar can be achieved when using 10% GP as replacement by cement;

By adding the steel fiber in the mortar it can be avoiding cracks and gives high durability. In mechanical strength steel fiber percentage of 1% in sand and 10% glass powder has obtained high strength.

The incorporation of steel fibers as reinforcement increased the compressive strength of mortar. The 1% steel fiber reinforcement reaches highest compressive of 25.6 MPa, which was 19% higher than the CM;

The inclusion of steel fibers combined with glass powder in mortar improves the compressive strength of mortar but the increase is relatively small. The increase ranged from 19.6% to 25.6%. The addition of steel fiber in mortar however, had significant impact on the flexural strength due to the improvement in flexibility behaviour of mortar. The increase in flexural strength ranged from 17% to 42.10%;

The microstructure of the mortar formulated with 10% glass powder and 1% steel fiber (M10G 1F) give a very dense structure to mortar, and the SF are heavily bonded to the cementitious matrix.

ACKNOWLEDGMENT

The authors express their acknowledgement for any help provided by all people contributing in the preparation of the present work.

REFERENCES

[1] Ali, S., Kumar, H., Rizvi, S.H., Raza, M.S., Ansari, J.K. (2020). Effects of steel fibres on fresh and hardened properties of cement concrete. Civil and Environmental Engineering Reports, 30(3): 186-199. https://doi.org/10.2478/ceer-2020-0039

[2] Okeola, A.A., Abuodha, S.O., Mwero, J. (2018). Experimental investigation of the physical and mechanical properties of sisal fiber-reinforced concrete. Fibers, 6(3): 53. https://doi.org/10.3390/fib6030053

[3] Rana, A. (2013). Some studies on steel fiber reinforced concrete. International Journal of Emerging Technology and Advanced Engineering, 3(1): 120-127.

[4] Sorelli, L.G., Meda, A., Plizzari, G.A. (2006). Steel fiber concrete slabs on ground: A structural matter. ACI Materials Journal, 103(4): 551-558. https://doi.org/10.14359/16431

[5] Ahamed, M.S., Ravichandran, P., Krishnaraja, A.R. (2021). Natural fibers in concrete–A review. In IOP Conference Series: Materials Science and Engineering, 1055(1): 012038. https://doi.org/10.1088/1757-899X/1055/1/012038

[6] Das, S., Sobuz, M.H.R., Tam, V.W., Akid, A.S.M., Sutan, N.M., Rahman, F.M. (2020). Effects of incorporating hybrid fibres on rheological and mechanical properties of fibre reinforced concrete. Construction and Building Materials, 262: 120561. https://doi.org/10.1016/j.conbuildmat.2020.120561

[7] Islam, A., Shuvo, A.K., Chowdhury, S.A., Sharmin, S., Hasan, M. (2021). A comparative study on the properties of natural, synthetic and steel fibre reinforced concrete. Journal of Civil Engineering and Construction, 10(4): 216-224. https://doi.org/10.32732/jcec.2021.10.4.216

[8] Mangi, S.A., Ibrahim, M.H.W., Jamaluddin, N., Arshad, M.F., Memon, F.A., Jaya, R.P., Shahidan, S. (2018). A review on potential use of coal bottom ash as a supplementary cementing material in sustainable concrete construction. International Journal of Integrated Engineering, 10(9): 28-36. https://doi.org/10.30880/ijie.2018.10.09.006

[9] Sandhu, A.R., Rind, T.A., Kalhoro, S.A., Lohano, R., Laghari, F.H. (2019). Effect on the compressive strength of mortars using ground granulated blast furnace slag as a partial replacement of cement. Journal of Applied Engineering Sciences, 9(2): 183-186. https://doi.org/10.2478/jaes-2019-0025

[10] Mangi, S.A., Wan Ibrahim, M.H., Jamaluddin, N., Arshad, M.F., Mudjanarko, S.W. (2019). Recycling of coal ash in concrete as a partial cementitious resource. Resources, 8(2): 99. https://doi.org/10.3390/resources8020099

[11] Rawat, V., Kumar, R., Sachan, A.K., Tripathi, D. (2021). Effect of steel fibre on mechanical properties of metakaolin - mixed concrete. In Recent Advances in Structural Engineering, pp. 101-110. https://doi.org/10.1007/978-981-33-6389-2_11

[12] Ahmad, W., Farooq, S.H., Usman, M., Khan, M., Ahmad, A., Aslam, F., Al Yousef, R., Al Abduljabbar, H., Sufian, M. (2020). Effect of coconut fiber length and content on properties of high strength concrete. Materials, 13(5): 1075. https://doi.org/10.3390/ma13051075

[13] Verma, N., Kumar, H., Jain, A.K. (2016). Effect of steel fiber and glass fiber on mechanical properties of concrete. IJSTE-International Journal of Science Technology & Engineering, 3(3): 173-178.

[14] Belouadah, M., Rahmouni, Z.E.A., Tebbal, N. (2019). Experimental characterization of ordinary concretes obtained by adding construction waste (glass, marble). Procedia Computer Science, 158: 153-162. https://doi.org/10.1016/j.procs.2019.09.038

[15] Belouadah, M., Rahmouni, Z.E.A., Tebbal, N. (2019). Influence of the addition of glass powder and marble powder on the physical and mechanical behavior of composite cement. Procedia Computer Science, 158: 366-375. https://doi.org/10.1016/j.procs.2019.09.064

[16] Mohammad yan-Yasouj, S.E., Ghaderi, A. (2020). Experimental investigation of waste glass powder, basalt fibre, and carbon nanotube on the mechanical properties of concrete. Construction and Building Materials, 252: 119115. https://doi.org/10.1016/j.conbuildmat.2020.119115

[17] Koksal, F., Yıldırım, M.S., Benli, A., Gencel, O. (2021). Hybrid effect of micro-steel and basalt fibers on physico-mechanical properties and durability of mortars with silica fume. Case Studies in Construction Materials, 15: e00649. https://doi.org/10.1016/j.cscm.2021.e00649.

[18] Periquito, M.D.S., Magalhães, M.D.S. (2017). Mechanical behaviour of steel fiber reinforced concrete with stone powder. Matéria (Rio de Janeiro), 22(2). https://doi.org/10.1590/S1517-707620170002.0172

[19] Hadjoudja, M., Benzaid, R., Mesbah, H.A., Makhloufi, Z., Bederina, M. (2021). Effect of mineral additions and metal fibers on the resistance of cracking of the dune sand concretes. Iranian Journal of Science and Technology, Transactions of Civil Engineering, 45(3): 1523-1537. https://doi.org/10.1007/s40996-021-00647-2

[20] Mahesh, V., Joladarashi, S., Kulkarni, S.M. (2020). Evaluation of tensile strength and slurry erosive behaviour of jute reinforced natural rubber based flexible composite. Revue des Composites et des Matériaux Avancés, 30(2): 77-82. https://doi.org/10.18280/rcma.300204

[21] Sangeetha, P. (2011). Study on the compression and impact strength of GFRC with combination of admixtures. Journal of Engineering Research and Studies, 2(2): 36-40.

[22] Rahma, A. (2013). Concrete mix design method, according to a referential structure and the aggregates specific surface area. Journal of Engineering Science, Damascus University, 29: 15-25.

[23] Chadli, M., Tebbal, N., Mellas, M. (2021). Impact of elevated temperatures on the behavior and microstructure of reactive powder concrete. Construction and Building

Materials, 300: 124031. https://doi.org/10.1016/j.conbuildmat.2021.124031
[24] NF EN 933-1. (2012). Tests for geometrical properties of aggregates-Part 1: Determination of particle size distribution- particle size analysis by sieving. https://www.boutique.afnor.org/fr-fr/norme/nf-en-9331/essais-pour-determiner-les-caracteristiques-geometriques-des-granulats-part/fa163900/39221.
[25] Technical data sheet. MEDA-AIR, Granitex, Algiers. https://silex-dz.com/wp-content/uploads/2020/04/MEDA-AIR.pdf, accessed on Dec. 10, 2021.
[26] Tebbal, N., Rahmouni, Z.E.A. (2019). Effects of high temperatures on mortar containing Portland cement and an Air-Entraining Agent. Academic Journal of Civil Engineering, 37(1): 92-96. https://doi.org/10.26168/ajce.37.1.19
[27] NF EN 196-1. (2016). Méthodes d'essais des ciments – Partie 1: détermination des résistances mécaniques. https://www.boutique.afnor.org/fr-fr/norme/nf-en-1961/methodes-dessais-des-ciments-partie-1-determination-des-resistances/fa184622/57803#AreasStoreProductsSummaryView, accessed on Dec. 10, 2021.
[28] AFPC-AFREM Groupe de travail Durabilité, A. A. G. des bétons (1998). Recommended test methods for measuring the parameters associated to durability. Proceedings des Journées Techniques AFPC-AFREM: Durabilité des Bétons, Dec, 11-12. https://www.ifsttar.fr/fileadmin/user_upload/editions/lcpc/GuideTechnique/GuideTechnique-LCPC-MAITROUB.pdf, accessed on Dec. 10, 2021.
[29] Bhat, V.V., Rao, N.B. (2014). Influence of glass powder on the properties of concrete. International Journal of Engineering Trends and Technology, 16(5): 196-199. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.678.1739&rep=rep1&type=pdf.
[30] Belouadah, M., Rahmouni, Z.E.A., Tebbal, N. (2019). Influence of the addition of glass powder and marble powder on the physical and mechanical behavior of composite cement. Procedia Computer Science, 158: 366-375. https://doi.org/10.1016/j.procs.2019.09.064
[31] Zitouni, S., Maza, M., Tebbal, N., Rahmouni, Z.E.A. (2022). Impact of rolled and crushed aggregate with natural pozzolan on the behavior of HPC. Annales de Chimie - Science des Matériaux, 46(1): 45-52. https://doi.org/10.18280/acsm.460106
[32] Mekki, M., Abdelghani, N., Zitouni, S. (2018). Effect of crushed glass aggregates on the physico-mechanical properties of micro-concrete. Lebanese Science Journal, 19(2): 210-228. https://doi.org/10.22453/LSJ-019.2.210228

NOMENCLATURE

CEM II/A	Portland cement type
WG	waste glass
DS	dune sand
MC	Control mortar
M5G 0F	mortar with 5% WG and 0% fiber
M10G 0F	mortar with 10% WG and 0% fiber
M5G 1F	mortar with 5% WG and 1% fiber
M5G 2F	mortar with 5% WG and 2% fiber
M10G 1F	mortar with 10% WG and 1% fiber
M10G 2F	mortar with 10% WG and 2% fiber
NF EN	European Committee for Standarization
AEA	Air-Entraining Agent