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Mechanical and durability properties of concrete incorporating glass and plastic waste

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Abstract. The main objective of this work is to contribute to the valorization of plastic and glass waste in the improvement of concrete properties. Waste glass after grinding was used as a partial replacement of the cement with a percentage of 15%. The plastic waste was cut and introduced as fibers with 1% by the total volume of the mixture. Mechanical and durability tests were conducted for various mixtures of concrete as compressive and flexural strengths, water absorption, ultrasonic pulse velocity, and acid attack. Also, other in-depth analyses were performed on samples of each variant such as X-ray diffraction (XRD), thermogravimetric analysis (DSC-TGA), and scanning electron microscope (SEM). The results show that the addition of glass powder or plastic fibers or a combination of both in concrete improved in the compression and flexural strengths in the long term. The highest compressive strength was obtained in the mix which combines the two wastes about 26.72% of increase compared to the control concrete. The flexural strength increased in the mixture containing the glass powder. Therefore, the mixture with two wastes exhibits better resistance to aggressive sulfuric acid attack, and incorporating glass powder improves the ultrasonic pulse velocity.

Keywords: mechanical; durability; concrete; waste glass; plastic waste

1. Introduction

Concrete is the most used material in the world after water and can be poured and molded in any requested shape, thus it is used in a large quantity. Concrete consists of a cementitious paste with aggregates (sand+gravel) (Olutoge 2016).

The use of waste in the construction industry has two important interests, the first is the environmental effect addressed by the disposal of waste and the second is the economic impact.

This waste has the advantage of being available with a high quantity and low cost (Sadiq and Khattak 2015). Glass is one of the most used materials in our lives in many forms. It is a transparent solid that results from the melting at a high temperature of a mixture of silica, sodium carbonate, and calcium carbonate then by cooling and transformation into solid without crystallization (Hussain and Chandak 2015).

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The pozzolanic properties of glass fine particles allow using glass waste as a partial replacement of cement or cementitious material in the manufacture of concrete (Jani and Hogland 2014). Plastics become necessary elements and an important part of our lives. The amount of plastic used each year in steady growth. The factors that explain this amazing growth are its low density, strength, long life, lightweight, and feeble costs. The greater part of the plastic waste is low-density polyethylene (LDPE) at about 23%, followed by 17.3% high-density polyethylene, 18.5% polypropylene, 12.3% polystyrene (PS/expanded PS), 10.7% polyvinyl chloride, 8.5% polyethylene terephthalate and 9.7% other types (Association of Plastics manufactures in Europe 2004) (Siddique *et al.* 2008).

Concrete is characterized by disadvantages such as low tensile strength, high weight, and low ductility. These negative aspects prompted researchers to introduce materials into concrete to improve these properties such as fibers. Reinforcing the concrete with fibers plays an important role in crack elimination, increases tensile strength, impact resistance, fatigue resistance, and ductility of concrete (Chavan and Rao 2016). For this reason, various researchers have examined the use of plastic waste in the form of fibers in concrete. This work presents an experimental study on the use of waste glass as partial replacement of cement in the concrete, as well as the addition of plastic fibers in the total volume.

Several authors have examined the effect of particle size of glass powder as partial replacement of cement in concrete. The test results showed that concrete containing

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Table 1 Physical characteristics of cement

Sr. No	Characteristics	Values
1	Normal consistency (%)	26.5±2
2	Fineness according to Blaine method cm^2/g	3700-5200
3	Initial Setting (min)	150±30
4	Final Setting (min)	230±50
5	Shrinkage (μm/m)	<1000
6	Expansion (mm)	<3.0

Table 2 Comparative chemical properties of cement and glass powder

Chemical composition	Cement (%)	Glass powder (%)
SiO_2	17.50	70.90
Al_2O_3	4.36	1.93
Fe_2O_3	3.10	0.40
CaO	60.40	13.30
MgO	1.70	0.80
SO_3	2.50	0.06
(K_2O+ Na_2O)	0.58	12.73
Loss on Ignition	10	0.50

glass powder with a finer grain size has a pozzolanic behavior, which gives a higher compressive strength (Zakir *et al*. 2016, Harish *et al*. 2016).

Mwizerwa and Garg (2017) studied the effects of different colors of glass waste on the properties of concrete when used as a partial replacement for cement with a grain size of less than 90 μm. They showed that green glass offers a higher resistance than clear glass with the same substitution rate and the optimal percentage is 30% in terms of compressive, tensile, and flexural strengths. Many works have demonstrated the possibility of replacing cement by glass powder with an optimum percentage. Studies found that the optimum percentage of replacement is 15% (Bashir *et al*. 2016, Khan *et al.* 2015). On the contrary, other researchers showed that the optimum percentage of substitutions for acceptable compressive and flexural strength is 20% at 7 and 28 days of curing (Talsania *et al*. 2015, Shanmuguanathan *et al*. 2017). On the other hand, from the results, they concluded that a 10% replacement is the best proportion (Vandhiyan *et al.* 2013, Mounika *et al*. 2017). Rahman and Uddin (2018) found that 30% of replacement of cement by glass powder achieves maximum tensile strength by splitting compared to ordinary concrete at 28 days. The study conducted by Aliabdo *et al.* (2016) on the inclusion of glass powder as replacement and addition to cement at the percentage of 5 to 25% showed that 15% content of glass powder as cement additive increases the compressive strength by 16% and achieved better performance compared to variants produced by replacement.

Many researchers have investigated the use of plastic waste in concrete in the form of fibers which more parameters may affect the physical and mechanical properties of concrete, such as the percentage, the shape (length and width) of fiber, and the nature of the plastic.

Chacko and George (2017) studied the performance of concretes with PET fibers (thermoplastic polyester) at different lengths of 5, 15, and 20 mm with a constant 2 mm width. Test results showed that the increase in the strength for variants having aspect ratio AR=2.5 corresponding to the fibers with 5 mm length. Other works examined the possibility of using bottle waste in the variants elaborated at 1% by total volume and indicated a significant improvement of strength (Prabhu *et al*. 2014, Lawrance and George 2016). Bhogayata *et al.* (2017) studied the properties of concrete reinforced with metalized plastic waste MPW with 5 mm, 10 mm, and 20 mm with a varying fraction from 0 to 2% by volume of the mix. They showed that the addition of MPW at 1% dose and type of 20 mm presents higher tensile strength by splitting compared to the reference concrete. Shahidan *et al.* (2018), NiBudey *et al.* (2018) found that the optimum percentage for recycled PET fibers introduced in concrete is 1%. On the contrary, Sanjaykumar and Daule (2017) demonstrated that the inclusion of 1.5% of PET fibers enhanced tensile strength. The results of Karanth *et al*. (2017) showed that the optimal percentage of plastic waste fibers that give concrete better shear and impact resistance is 1.25%.

Taherkhani (2014) introduced PET fibers with different lengths of 1, 2, and 3 cm with the same width 2 mm at the percentage from 0.5 to 1% by volume of the mix. They concluded that the compressive strength at 7 and 28 days decreases with increasing length and fiber content. The lowest values of resistance were observed in mixes containing 1% fiber with 3 cm length. In the work of Borg *et al.* (2016) different types of recycled PET fibers shredded, straight and deformed with different fiber lengths (30 mm and 50 mm) were added with percentages varying from 0.5 to 1%. They demonstrated that the use of shredded fibers in concrete leads to interesting improvements in the mechanical performance of concrete. According to research works on both wastes glass and plastic, agree on optimum parameters: the replacement rate of cement by glass powder is 15% with particle size less than 80 μm. The percentage of plastic fibers by total volume on the concrete mix is 1% with the aspect ratio AR=2.5. Many types of research were carried on the valorization of waste glass in the powder form, also waste plastic in the shape of fiber, which showed an improvement of physic mechanical properties of mortars and concrete, but it was noted that there is no study of the possibility of combined valorization of two wastes (glass and plastic), which is the objective of this study.

2. Materials and mix proportions

2.1 Materials

Two gravel classes with sizes of (3/8 and 8/16) and a unit weight of 2640 kg/m^3 and 2690 kg/m^3 respectively, were used as coarse aggregate in our work. The sand used is crushed with a density of 2630 kg/m^3 having a fineness modulus of 2,99. The Portland cement used in this study is CEM II conforming to the Algerian standard NA 442 (2013). Its physic characteristics are presented in Table 1.

The glass powder introduced from the packaging of alcoholic beverages collected, washed, and crushed using a

(a) Glass waste

(b) Plastic waste

Fig. 1 Glass and plastic waste

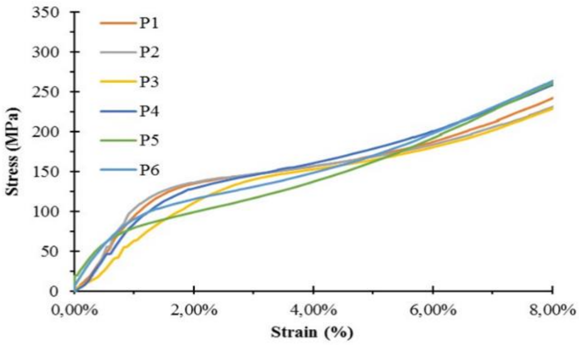


Fig. 2 The tensile curve (stress/ strain) of plastic fibers

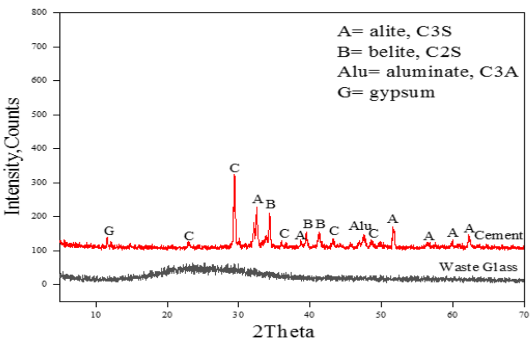


Fig. 3 XRD patterns for cement and waste glass

ball mill until the desired fineness of 80 μm with 2.60 specific gravity, added by a partial replacement of 15% related to the cement (Fig. 1). Table 2 illustrates the chemical characteristics of glass powder and cement.

The plastic fibers used in our research is PET polyester high-strength used as packaging yarn in an industry with AR=2.5 (aspect ratio: a length of 1.5 cm with a width of 0.6 cm) introduced into the concrete with 1% by the total volume of the mix (Fig. 1). Fig. 2 shows the stress-strain curve of the tensile strength test on the plastic fibers used and the test was conducted as per ASTM D882-02 (2002). The plasticizer water reducer (SIKAPLAST BV 40+) was added to all variants elaborated with a constant dose (2% by weight of cement).

Fig. 3 shows XRD of cement and glass powder, indicating the presence of crystalline clinker phases, which are C_3S, C_2S, and C_3A minerals with calcium silica phase in

Table 3 Proportion of concrete mixtures

Concrete type	Cement (kg/m^3)	Water (kg/m^3)	Sand (kg/m^3)	Gravel 3/8 (kg/m^3)	Gravel 8/16 (kg/m^3)	Plastic fiber (kg/m^3)	W/C
CR	360	177	718	87	/	/	0.49
GP	306	177	718	87	54	/	0.49
PF	360	177	718	87	/	23	0.49
CM	306	177	718	87	54	23	0.49

cement. The glass powder corresponds to the amorphous nature of glass without any crystalline peaks with a broad peak at 25°(2θ) which represents the amorphous silica.

2.2 Mix proportions

In this study, four concrete mixtures were prepared with a 0.49 water-cement ratio. The first was the control concrete mix (CR), the second containing glass powder as partial replacement of cement with 15% (GP), the third elaborated by the introduction of plastic fibers at 1% by total volume (PF) and the last contains glass powder and plastic fibers with the same percentage, 15% by cement weight and 1% by total volume respectively (CM). The composition of the elaborated variants is mentioned in Table 3. All formulations were prepared according to the Dreux Gorisse method (Festa and Dreux 1998).

3. Experimental methods

The samples for XRD and (DSC-TGA) analysis were prepared by grinding and sieving to obtain fineness smaller than 80 and 3,15 μm. The water absorption tests by capillarity and by immersion were carried out according to the specification of the standard documentation LNEC Portugal E393-1993 (1993) and E 394-1993 (1993), respectively.

DSC-TGA thermal analysis was carried out by TA Instruments-SDT 2960 Simultaneous DSC-TGA at 25ºC to 1100ºC with a rate of 10ºC /min under an airflow rate of (80ml /min). XRD scan was from 5° to 70°(2θ) at a speed of 0.02°/s. In this study, observations under a scanning electron microscope were performed on all variants studied.

The compressive strength of all variants studied was

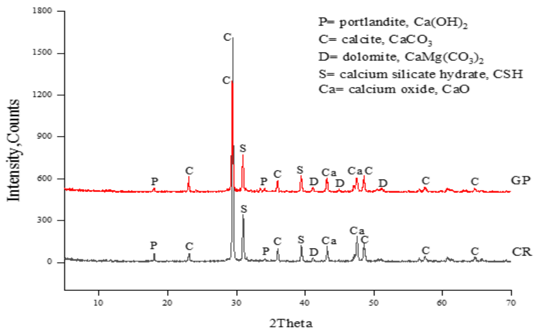


Fig. 4 X-Ray Diffraction Analysis for CR and GP concrete

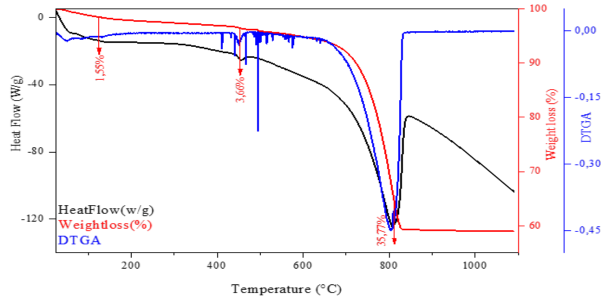


Fig. 6 DSC- TGA of concrete with glass powder (GP)

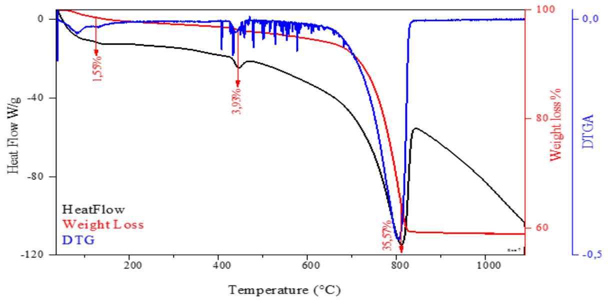


Fig. 5 DSC-TGA of control concrete (CR)

conducted according to NF EN 12390-3 (2003) on cubes (150×150×150) mm^3, using a compressive testing machine with a capacity of 3000 kN. The flexural strength was achieved according to NF EN 12390-5 (2001) on prisms (70×70×280) mm^3, using a three-point flexural machine.

The ultrasonic pulse velocity was determined as per standard NP EN 12504-3 (2007). We used four samples in each curing day for all previous tests.

The acid resistance test was carried out with a solution of sulfuric acid (H_2SO_4) at two concentrations of 5% and 10% in a laboratory at room temperature. Two sample sizes were used in this test for the four concrete mixes with (5×5×5) cm and (5×5×10) cm. The specimens were immersed in water for more than 48 hours before immersion in both solutions and the solution was renewed every 15 days to maintain a constant pH. The ratio of the change in mass of the sample to the initial mass, termed acid Mass Loss Factor (AMLF), after removing the sediment was calculated. (Goriparthi and Rao 2017).

4. Results and discussion

4.1 XRD and DSC-TGA analysis

X-ray diffraction results for CR and GP concrete mixes are shown in Fig. 4. The peaks in GP show the presence of the same mineralogical phases in the CR mix. There has been a decrease in the peaks indicating portlandite CH in GP compared to CR, which is explained by the consumption of $Ca(OH)_2$ by pozzolanic reaction due to the presence of glass powder to thus form calcium silicate hydrate CSH.

The mineralogical phases found in concrete are the main phase of calcite $CaCO_3$ at 29(2θ), also the portlandite at 18°(2θ) and 34°(2θ), the phase of dolomite $CaMg(CO_3)_2$ (principal peak at 31°(2θ)). Also, there have been the phases of calcium oxide CaO (main peak at 47°(2θ)) and finally CSH (principal peak at 39°(2θ)). This analysis confirms the pozzolanic effect of glass powder as forming additional CSH in concrete, after consumption of portlandite as mentioned in the works of Chabil (2009) and Toumi (2010).

The gravimetric thermal analysis (DSC-TGA) of the samples of control concrete is presented in Fig. 5, which shows the presence of three endothermic peaks, which are translated by the presence, in the first place, a mass loss at 125°C with 1.55% (about 0.54 mg) compared to the initial mass.

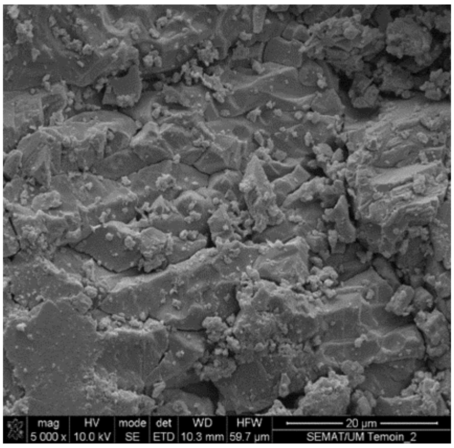
This phenomenon is explained by the evaporation of free water, the dehydration of calcium silicate hydrate, and ettringite (Fares 2009). In the second place, the peak noted at a temperature between 450°C and 550°C, which shows mass loss of 3.93% (1.37 mg), corresponds to the decomposition phenomena of the portlandite in free lime, according to reaction $Ca(OH)_2 \rightarrow CaO+H_2O$, that the authors mentioned in their work (Elkacemi *et al.* 2014). Finally, around 650°C and 850°C, a mass loss of 35.57% (about 12,41 mg), which illustrates the decomposition of calcium carbonate $CaCO_3$ as per the following reaction $CaCO_3 \rightarrow CaO+CO_2$ which releases carbon dioxide CO_2.

Fig. 6 shows the DSC-TGA curve of the GP concrete mix. The same mass loss value in the first peak of 1.55% indicates that there is no effect of glass powder in the concrete up to 125°C. There was a decrease in a mass loss in the second peak due to a reduction in the amount of portlandite that reacts with silica from the glass powder to form CSH. Also, it was noted an increase in mass loss in the third peak, which explains the increase in the amount of calcite due to pozzolanic reaction, thus the decomposition of $CaCO_3$ with a large amount (Belouadah *et al.* 2018).

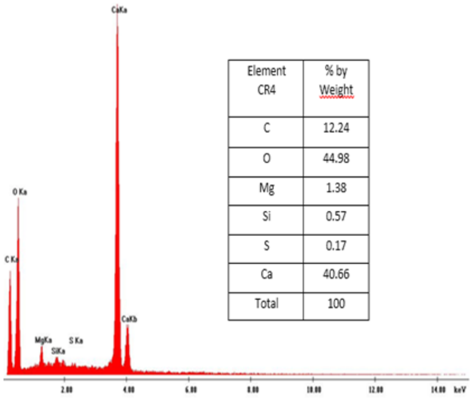
The thermal analysis effectively shows the pozzolanic reaction of glass powder, which is advantageous for the durability of concrete.

4.2 SEM characterization

SEM images of the control concrete samples (Fig. 7) show the existence of calcium silicate hydrate CSH with portlandite CH resulting from the hydration of the cement (the hydration of the minerals C_3S and C_2S) as previously confirmed by DRX results. The chemical analysis EDS detected the presence of calcium and oxygen largely with the presence of other elements (Mg, Si, S...).

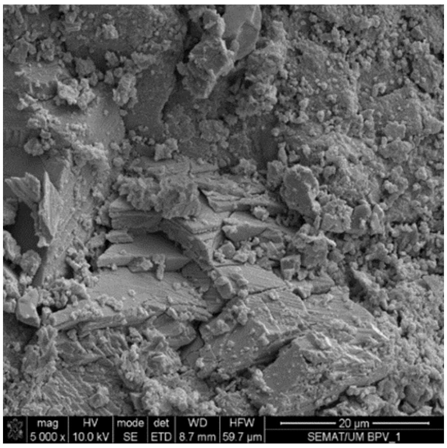


(a) SEM of control concrete

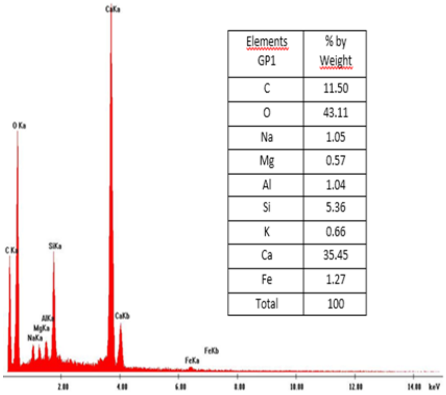


(b) EDS of control concrete

Fig. 7 SEM-EDS analysis of the control concrete

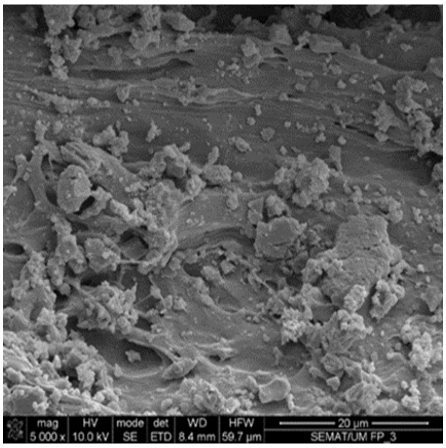


(a) SEM of GP mix

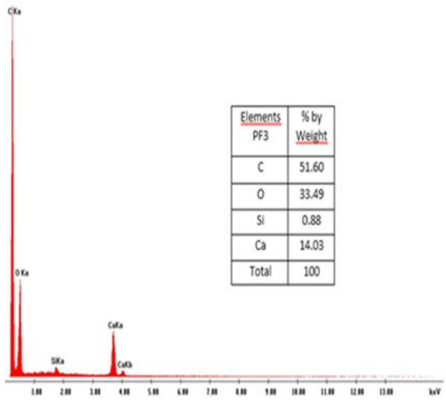


(b) EDS of GP mix

Fig. 8 Analysis SEM-EDS GP mix



(a) SEM of PF mix



(b) EDS of PF mix

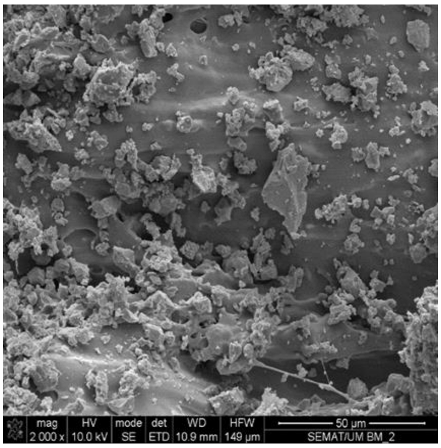
Fig. 9 Analysis SEM-EDS of PF mix

The microstructure of concrete with glass powder as partial replacement of cement (Fig. 8) shows the reduction of pores due to the glass powder filling of the voids. Also, we note the decrease in portlandite Ca $(OH)_2$ which combines with silica to form C-S-H according to the following reaction:

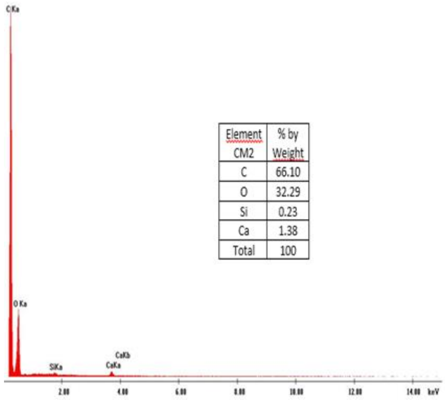
$$Ca(OH)_2 + SiO_2 + H_2O \rightarrow C\text{-}S\text{-}H$$

The chemical analysis (EDS) also revealed the presence of calcium and oxygen with the existence of other elements (Al, Na, K...). This seems to reveal the presence of the glass powder.

Fig. 9 shows the microstructure of concrete reinforced

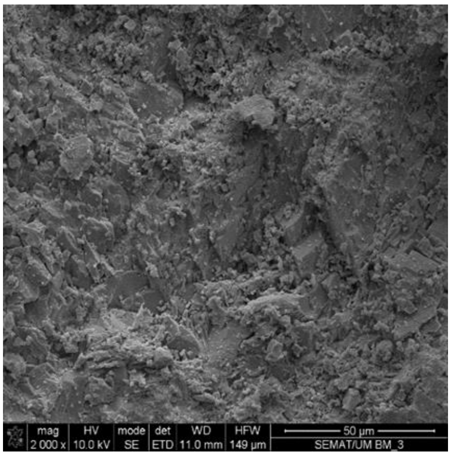


(a) SEM of CM mix

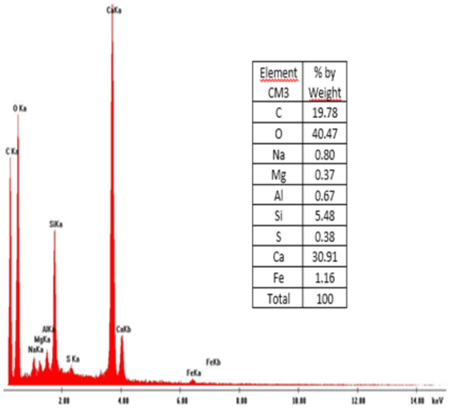


(b) EDS of CM mix

Fig. 10 Analysis SEM-EDS of CM mix



(a) SEM of CM mix



(b) EDS of CM mix

Fig. 11 Analysis SEM-EDS of CM mix in another point

with plastic fibers. There have been void with the presence of calcium silicate hydrate CSH and portlandite CH. The chemical analysis (EDS) showed the presence of a carbon content higher than 50%, this confirms the existence of the polymer.

Figs. 10 and 11 show the concrete microstructures with glass powder and plastic fibers. These figures illustrate the decrease in portlandite that reacts with silica to form CSH and consolidation of the structure due to the presence of the glass powder. The EDS chemical analysis (Fig. 10) shows the presence of a carbon content higher than 60%, this confirms the existence of the polymer and the EDS analysis (Fig. 11) notes the presence of the elements (Na, Al...) indicating the existence of the glass powder.

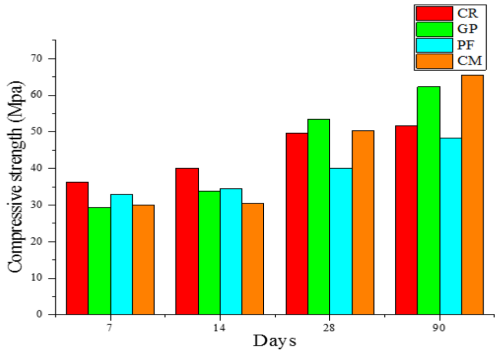


Fig. 12 The compressive strength of concrete at the curing ages of 7, 14, 28 and 90 days

4.3 Compressive strength

The results of the compression test are shown in Fig. 12. A decrease in strength is observed in all GP and CM mixes compared to the reference mix at 7 and 14 days, which is explained by the replacement of cement by glass powder. At 28 days, a 7.99% increase in strength was noted in the GP mixture, which was attributed to the pozzolanic reaction of the glass powder. Silica combines with portlandite to form calcium silicate hydrates, as shown in the DSC-TGA analysis in Fig. 6, by reducing the amount of CH and also due to the glass powder that fills the voids between the particles, thus reducing porosity. The same results were found by Dubey *et al.* (2016).

Besides, strength decreased in the PF mix compared to the control concrete in all curing ages, which is attributed to the lack of adequate bonding between the plastic fibers and the cement paste (Taherkhani 2014). In the CM mix, an increase of 1.78% compared to the reference concrete was noticed, this

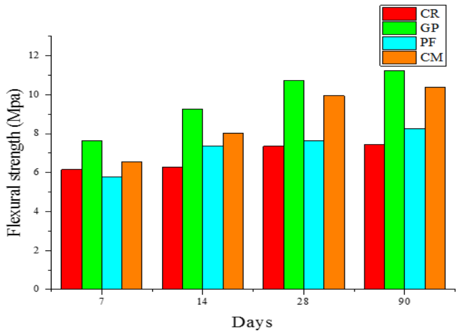


Fig. 13 The flexural strength of concrete at the curing ages of 7, 14, 28 and 90 days

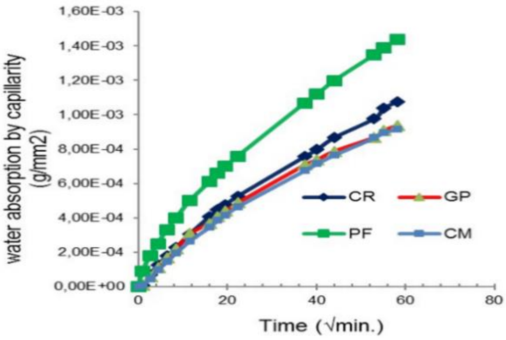


Fig. 14 Water absorption by capillarity of concretes as a function of time

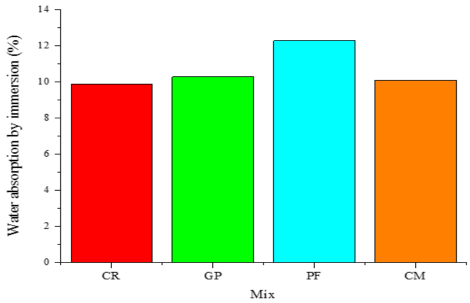


Fig. 15 Water absorption by immersion of the different concrete mixes

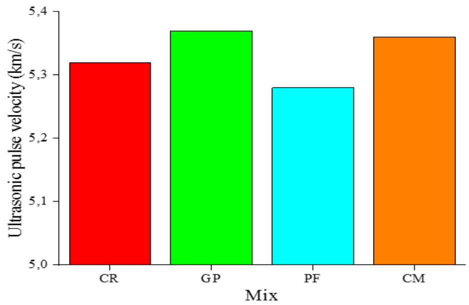


Fig. 16 The ultrasonic propagation velocity of different concretes

confirms the effective effect of glass powder compared to plastic fibers.

At 90 days, there was an increase in strength of 20.58%, 26.72% in GP and CM concretes, respectively. This increase indicates the continuation of the pozzolanic reaction of the glass powder, forming CSH in the mixtures. This has been confirmed by Du and Tan (2014) and as shown in the SEM analysis in Figs. 8 and 11 by decreasing the amount of portlandite.

4.4 Flexural strength

The results of the flexural strength tests are shown in Fig. 13. There is an increase in strength in the GP mixture compared to the control mixture of 24.07%, 47.26%, 46.26%, and 51.01% at 7, 14, 28, and 90 days, respectively. This increase is due to the pozzolanic reaction of the glass powder and the efficient filling of voids, which leads to a dense microstructure of the concrete (Rokdey *et al*. 2018).

On the other hand, there is an increase in the PF mixture of 17.22%, 3.81%, and 10.74% at 14, 28, and 90 days, respectively. This is explained by the reinforcement of the concrete with rough-surface fibers that reduce cracking. An increase in flexural strength was observed in the CM mix compared to the reference concrete of 6.50%, 28.07%, 35.37%, and 39.33% at 7, 14, 28, and 90 days curing, respectively. This is attributed to the combined presence of glass powder and plastic fibers in the mix, which shows a positive effect of the combined introduction of glass powder and plastic fibers on the mechanical behavior of the concrete in the long term (90 days).

4.5 Water absorption test by capillarity

The results are presented in Fig. 14. At the beginning of the test, it can be noticed that the water absorption by capillarity of all concrete increases rapidly, especially in concrete containing only plastic fibers (PF). The increase in absorption is similar for all concretes. The increase in PF concrete is due to the plastic fibers that create the voids between the concrete constituents. Absorption in GP and CM concretes is lower compared to PF and CR mix. This is related to the glass powder that fills the voids in the concrete mix.

4.6 Water absorption test by immersion

According to the results shown in Fig. 15. There is an increase in water absorption by immersion in the different GP, PF, and CM mixtures compared to the control mix. There has been a significant increase in PF concrete. This is related to the plastic fibers that create the voids in the matrix. In PF and CM concretes, a slight increase in water absorption compared to the reference concrete can be observed. This is due to the glass powder that fills the voids between the concrete constituents.

4.7 Ultrasonic pulse velocity

The results obtained show that the quality of the different concrete mixes is of excellent quality according to the standard (Fig. 16). There is a slight decrease in the velocity of PF concrete compared to the control concrete. This decrease may be due to the presence of plastic fibers which cause an increase in the pore size in the concrete as shown in the SEM analysis and lengthen the sound

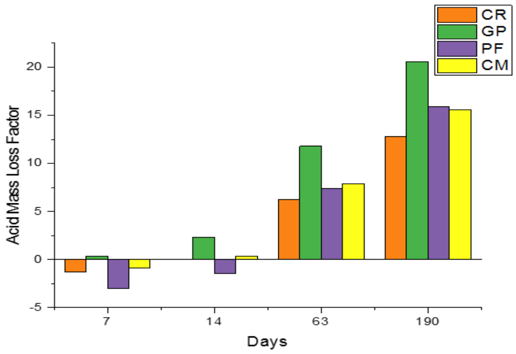


Fig. 17 Acid Mass Loss Factor for the different concrete mixes of (5×5×5) cm

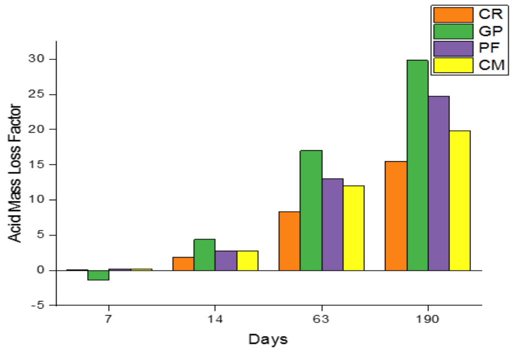


Fig. 18 Acid Mass Loss Factor for the different concrete mixes of (5×5×10) cm

propagation time. A slight increase in the propagation velocity is observed in GP and CM concretes. This is due to the glass powder filling the voids in the concrete and therefore a decrease in porosity.

4.8 Acid attack

Figs. 17 and 18 show the results of the mass loss after immersion in the 5% and 10% sulfuric acid solution. We notice in the different concrete mixes an increase in the mass loss at 63 and 193 days. The mass loss in the CM mixture gives lower values compared to the other mixtures at an advanced age. This is due to the effect of the glass powder, which is more important than the plastic fibers in this mixture, resulting in the filling of the voids between the concrete particles. In the PF mix, there has been an increase compared to the control concrete. This trend is related to the presence of plastic fibers that create voids between the concrete components. On the other hand, we observe a high value in the GP mixture. This may be due to a large amount of cementitious paste in these samples.

5. Conclusions

This work aims to study the effect of plastic and glass waste in the form of powder on the mechanical properties and microstructure of the concrete mixes studied.

The results of the experimental studies indicate:

• The use of glass in concrete mixtures reduces water absorption by capillarity and a slight increase in water absorption by immersion. This is attributed to the glass powder that fills the voids between the constituents of concrete.

• The introduction of plastic waste into the concrete increases water absorption by capillarity and immersion. This is due to the plastic fibers that create the voids in the matrix of the concrete.

• This study confirms the positive effect of the introduction of the finely ground glass powder (<80 μm), which is proved in the XRD and DSC-TGA tests by the consumption of portlandite by the pozzolanic reaction. This phenomenon is illustrated by decreases of portlandite peaks.

• The study of the microstructure of samples reveals an identification of variants in the presence of glass powder, which consolidates advantage concretes.

• The compressive strength decreased in the PF mix compared to the control concrete in all curing ages, this is due to the lack of adequate bonding between the plastic fibers in the concrete.

• The flexural strength results showed the advantage of introducing plastic fibers in the concrete.

• The inclusion of glass powder or plastic fibers or a combination of both in concrete improved in the compression and flexural strengths in the long term. It also enhances the durability of its concretes.

• The ultrasonic pulse velocity shows an improvement in mixtures containing waste glass and the addition of plastic fibers in concrete presents a decrease in the propagation velocity.

• The mixture containing glass powder and plastic fibers presents a better resistance to acid attack.

• Finally, this work provides a sustainability solution by reducing glass and plastic wastes.

References

Aliabdo, A.A., Abd Elmoaty, A.E.M. and Aboshama, A.Y. (2016), “Utilization of waste glass powder in the production of cement and concrete”, *Constr. Build. Mater.*, **124**, 866-877. http://dx.doi.org/10.1016/j.conbuildmat.2016.08.016.

ASTM D 882-02 (2002), Standard Test Method for Tensile Properties of Thin Plastic Sheeting, American National Standards Institute, New York, NY, USA.

Belouadah, M., Rahmouni, Z.E.A. and Tebbal, N. (2018), “Effects of glass powder on the characteristics of concrete subjected to high temperatures”, *Adv. Concrete Constr.*, **6**(3), 311-322. http://dx.doi.org/10.12989/acc.2018.6.3.311.

Bhogayata, A.C. and Arora, N.K. (2017), “Fresh and strength properties of concrete reinforced with metalized plastic waste fibers”, *Constr. Build. Mater.*, **146**, 455-463. http://dx.doi.org/10.1016/j.conbuildmat.2017.04.095.

Borg, R.P., Baldacchino, O. and Ferrara, L. (2016), “Early age performance and mechanical characteristics of recycled PET fibre reinforced concrete”, *Constr. Build. Mater.*, **108**, 29-47. https://doi.org/10.1016/j.conbuildmat.2016.01.029.

Bashir, A., Basit, A., Bhat, J. and Diwaker, D. (2016), “A felicity of glass powder when replaced with cement”, *Int. J. Emerg. Technol. Adv. Eng.*, **6**(7), 91-95.

Chabil, F.Z.D. (2009), “Carbonation of adjuvant concrete based on

Algerian local resources", Ph.D. Dissertation, University of Constantine, Constantine, Algeria.
Chacko, B. and George. D.S. (2017), "Performance of concrete with PET fibers", *Int. J. Eng. Sci. Invent. Re. Develop.*, **3**(11), 725-728.
Chavan, S. and Rao, P. (2016), "Utilization of waste pet bottle fibers in concrete as an innovation in building materials-(a review paper)", *Int. J. Eng. Res.*, **5**(1), 304-307.
Du, H. and Tan, K.H. (2014), "Waste glass powder as cement replacement in concrete", *J. Adv. Concrete Technol.*, **12**, 468-477. http://dx.doi.org/10.3151/jact.12.468.
Dubey, S., Goliya, S.S. and Dhakre, O.S. (2016), "Feasibility of study on effect of waste glass powder as a partial replacement of cement on compressive strength of concrete", *Int. J. Sci. Res. Develop.*, **4**(5), 38-41.
Elkacemi, S., Abahlous, L., Ait amar. S, Boukbir, L. and El alem, N. (2014), "Heat treatment of concrete and its influence on the mechanical properties", *Proceedings of the International Congress on Materials and Structural Stability*, Rabat, November.
Fares, H. (2009), "Mechanical and physicochemical properties of self-compacting concretes exposed to high temperatures", Ph.D. Dissertation, University of Cergy Pontoise, Paris, France.
Festa, J. and Dreux, G. (1998), *New Guide to Concrete and its Constituents*, 8th Edition, Eyrolles Group, Paris, France.
Goriparthi, MR. and Rao, GTD. (2017), "Effect of fly ash and GGBS combination on mechanical and durability properties of GPC", *Adv. Concrete Constr.*, **5**(4), 313-330. https://doi.org/10.12989/acc.2017.5.4.313.
Harish, B.A, Hanumesh. B.M, Siddesh T.M. and Siddhalingesh B.K. (2016), "An experimental investigation on partial replacement of cement by glass powder in concrete", *Int. Res. J. Eng. Technol.*, **3**(10), 1218-1224.
Hussain, M.V. and Chandak, R. (2015), "Strength properties of concrete containing waste glass powder", *Int. J. Eng. Res. Appl.*, **5**(4), 1-4.
Hussain, G. and Verma, G. (2016), "Experimental investigation on glass powder as partial replacement of cement for m-30 concrete", *Int. J. Sci. Res. Sci., Eng. Technol.*, **2**(4), 846-853.
Jani, Y. and Hogland, W. (2014), "Waste glass in the production of cement and concrete-A review", *J. Environ. Chemi. Eng.*, **2**(3), 1767-1775. http://dx.doi.org/10.1016/j.jece.2014.03.016.
Karanth, S.S., Ghorpade, V.G. and Rao, H.S. (2017), "Shear and impact strength of waste plastic fibre reinforced concrete", *Adv. Concrete Constr.*, **5**(2), 173-182. https://doi.org/10.12989/acc.2017.5.2.173.
Khan, F.A., Fahad, M., Shahzada, K., Alam, H. and Ali, N. (2015), "Utilization of waste glass powder as a partial replacement of cement in concrete", *Int. J. Adv. Struct. Geotech. Eng.*, **4**(3), 181-185.
Lawrance, L. and George. D.S. (2016), "Study on properties of concrete with crimped pet fibres", *Int. J. Innov. Res. Sci. Eng. Technol.*, **5**(6), 9843-9850. http://dx.doi.org/10.15680/IJIRSET.2016.0506045.
LNEC E 393-1993 (1993), Concrete, Determination of the Absorption of Water through Capillarity, National Laboratory of Civil Engineering, Lisbon, Portugal.
Mounika, M., Lalith, B.V., Rao, V.R. and Lalitha, G. (2017), "Experimental study on strength and parameters of concrete by partial replacement of cement with recycled crushed glass powder", *Int. J. Civil Eng. Technol.*, **8**(5), 444-450.
Mwizerwa, F. and Garg, A. (2017), "Experimental study on effects on properties of concrete with differents colours of glass powder as a partial replacement of concrete", *Int. J. Civil Eng. Technol.*, **8**(4), 1639-1644.
NA 442 (2013), Cement Composition, Specifications and Conformity Criteria of Current Cement, Alger, Algeria.
NF EN 12390-3 (2003), Testing Hardened Concrete-Part 3: Compressive Strength of Test Specimens, European Committee for Standardization, Brussels, Belgium.
NF EN 12390-5 (2001), Testing Hardened Concrete-Part 5: Flexural Strength of Test Specimens, European Committee for Standardization, Brussels, Belgium.
NP EN 12504-4 (2007), Testing Concrete in Structures-Part 4: Determination of Ultrasonic Pulse Velocity, European Committee for Standardization, Brussels, Belgium.
Nibudey, R.N., Nagarnaik, P.B., Parbat, D.K. and Pande, A.M. (2013), "Strength and fracture properties of post consumed waste plastic fiber reinforced concrete", *Int. J. Civil Struct. Environ. Infrastrt. Eng. Res. Develop.*, **3**(2), 9-16. http://dx.doi.org/10.6088/ijcser.201304010018.
Olutoge, FA. (2016), "Effect of waste glass powder (wgp) on the mechanical properties of concrete", *Am. J. Eng. Res.*, **5**(11), 213-220.
Prabhu, G., Kumar, C.A., Pandiyaraj, R., Rajesh, P. and Kumar, L.S. (2014), "Study on utilization of waste pet bottle fiber in concrete", *Int. J. Res. Eng. Technol.*, **2**(5), 233-240.
Rahman, S. and Uddin M.U. (2018), "Experimental investigation of concrete with glass powder as partial replacement of cement", *Civil Eng. Archit.*, **6**(3), 149-154.
Rokdey, M.S.N., Dhawale, G.D. and Wagh, M.S.A. (2018), "Partial replacement of cement by using refused glass powder in concrete for strengthening", *Int. Adv. Res. J. Sci. Eng. Technol.*, **5**(5), 77-82. http://dx.doi.org/10.17148/IARJSET.2018.5513.
Sadiq, M.M. and Khattak, M.R. (2015), "Literature review on different waste materials use in concrete", *J. Emerg. Technol. Innov. Res.*, **2**(6), 1800-1803.
Sanjaykumar, B. and Daule, S.N. (2017), "Use of plastic fiber in the concrete", *Int. J. Civil Eng.*, **4**(11), 4-7. http://dx.doi.org/10.14445/23488352/ijce-v4i11p102.
Shahidan, S., Ranle, N.A., Zuki, S.S.M., Khalid, F.S., Ridzuan, A.R.M. and Nazri, F.M. (2018), "Concrete incorporated with optimum percentages of recycled polyethylene terephthalate (pet) bottle fiber", *Int. J. Integ. Eng.*, **10**(1), 1-8.
Shanmuguanathan, N., Gokila. R, Parameshwari. T. and Naveen. K.S.H. (2017), "Study and experimental investigation of partial replacement of waste glass powder as cement in concrete", *Int. J. Eng. Trend. Technol.*, **45**(4), 171-175.
Siddique, R., Khatib, J. and Kaur, I. (2008), "Use of recycled plastic in concrete: a review", *Waste Manage.*, **28**(10), 1835-1852. http://dx.doi.org/10.1016/j.wasman.2007.09.011.
Taherkhani, H. (2014), "An investigation on the properties of the concrete containing waste pet fibers", *Int. J. Sci. Eng. Invest.*, **3**(27), 37-43.
Toumi, B. (2010), "Study of the influence of high temperatures on concrete behavior", Ph.D. Dissertation, Mentouri University of Constantine, Constantine, Algeria.
Talsania, S., Pitroda, J. and Vyas, C. (2015), "Experimental investigation for partial replacement of cement with waste glass powder on pervious concrete", *Proceedings of the International Conference on Engineering: Issues, opportunities, and Challenges for Development*, Bardoli, India, April.
Vandhiyan, R., Ramkumar, K. and Ramya, R. (2013), "Experimental study on replacement of cement by glass powder", *Int. J. Eng. Res. Technol.*, **2**(5), 234-238.
Zakir, M, Qadri, S.I. and Siwach. E.R. (2016), "Experimental evaluation of waste glass powder as a partial replacement of cement in concrete", *Int. J. Re. Innov. Eng. Res.*, **1**(8), 71-75.

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