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EFFECT OF CEMENT DOSING WITHOUT ADDITIONS (CPA) ON HIGH-PERFORMANCE AND ORDINARY CONCRETE BASED GLASS POWDER AS FINE PARTIAL CEMENT REPLACEMENT - A COMPARATIVE STUDY

ABSTRACT

The main objective of this paper research is a comparative study on the effect of the glass powder (GP) substitute from collected and recycled glass waste, as a fine partial cement replacement on the mechanical performance and durability of high performance concrete (HPC) and ordinary concrete (OC). For this two cement dosing were used of 400 kg/m^3 to formulate OC and 450 kg/m^3 to formulate HPC, and GP as considered binder like cement and not as fine addition, hence binder represent the sum of cement with GP (L=C+GP) with which will be made our two concretes formulation. Two ratios were used for the Water/Binder (W/B), the first W/B=0.35 for the HPC and the second W/B=0.5 for the OC, this ration is very important to fix the concentration of superplasticizer. A percentage of 10% and 20% substitution of cement CPA without additions noted CEM I 52.5 by the glass powder with fineness of 3600 cm ^{2}/g are used. The evaluation of the compressive strength was followed from 7 to 365 days in order to study the behavior of the GP at different ages affected by the cement dosing and the ratio W/B compared to the reference concrete without GP for the two concretes HPC and OC. At 28 days the strengths of concretes with GP is affected by the replacement of a quantity of cement since the two reference concretes were superior but beyond this age an inverse behavior is noticed such that results obtained at age of 365 days seem to be advantageous in terms of savings in the quantity of cement used by interpreting the compressive strength, and the decrease in quantity of water in the mixtures offers a remarkable difference between the two concretes studied by using 20 % of GP as replacement of cement.

Keywords: *glass powder (GP); cement CPA; partial replacement; ratio W/B; high performance concrete; ordinary concrete, compressive strength*

INTRODUCTION

Due to need in large quantities to meet high demands of construction, economic and environmental problems are generated by the cement manufacturing industries, high greenhouse gas emissions, intensive use of energy and extreme exploitation of natural resources [1], so the production of cement (binder in construction) is an energy-intensive and highly polluting process which contributes about 5-8% to global CO_2 emissions [2].

The recycling of waste on all these forms in concrete [3-6] has experienced a revolution during these last years, glass is one of these waste, being a very durable material and infinitely recyclable, glass is principally composed of silica it is necessary to take advantage of glass waste and thanks to these advantages, the use of glass in the manufacture of concrete becomes an interesting subject and many advances have been made in this regard [7].

The glass in concrete can manifest, depending on the size of its particles, two types of behaviour with antagonistic quansequences: either an alkali-silica reaction type (RAS) causing adverse effects if the glass is used as glass aggregate or sand [8, 9] at low cost is this RAS is the result of the reaction of amorphous silica of an aggregate with hydroxyl and alkaline ions present in the pore solution of the concrete, and which gives rise to a swelling gel causing the concrete cracking, either a second poozolanic reaction [10] beneficial for the structure. In order to clarify the difference between the two reactions poozolanic and alkali-silica, by taking into account all the research work mentioned in the bibliography and mainly the work of Iddir [11, 12] delaying these two reactions, we have drawn up a diagram summarizing and well understanding represented by the Figure 1. Also Iddir [11, 12] showed that pozzolanic activity increases with the fineness of glass particles, confirmed by the formation C-S-H and a 10% increase in compressive strength, but slight activity is detected for large drawn glass particles, with swelling and expansion translated by cracks and alkali-silica gels observed at SEM.

A grinding of the glass to a greater fineness suggests the use of this material as binder after the work [13, 14] or the silica containing in glass reacts with the lime produced by the reaction of the cement, thus creating components with binding properties: it’s the poozolanic reaction.

Glass powder can be used in the manufacture of concretes and these derivatives as a fine addition by considerate a ratio water/ cement in the formulation or as a cementitious substitute by replacing a fraction of cement [15, 16] by considering a ratio water/ Binder which sum the amount of cement and glass powder. The work of [17] showed that working with the two ration conclude that concretes prepared with W/C are more strength than that prepared with W/B and justified by the decrease in the water amount by glass powder replacement 20% cement with CEM II 42.5, however a firm consistency of concrete has been obtained.

Belouadah [18] in his work approved that concrete with glass powder (5% and 10% replacement cement) is more advantageous in compressive strength subjected to high temperature temperatures 20, 200, 400, and 600°C because the hydration of cement and the pozzolanic reaction are simultaneously promoted.

Cement dosing, fineness, water quantities and aggregates nature have important roles in the formulation of all concretes [19-21], it define the nature and the future compressive strength, in literature methods formulation, if we have a high cement dosing and a small amount of water or E/C less than 0.5 and fine additives (silica fume, slag, fly ash ….) then a high performance concrete is obtained and if cement dosing is low and big amount of water or E/C greater than 0.5 an ordinary concrete is resulted. The latest work has reinforced the understanding of the effect applied by glass waste in the elaboration of concrete, [22] using several glass fineness in partial replacement of both cement and sand, but introducing steel fibers and silica fume by working with fixed ration Water-Binder, the result show that use 20% of replacement cement by glass powder and 0% sand replacement gave the best compressive strength. In the context of chemical durability in a solution NH_4NO_3, [23] found according to a 60-day immersion in this solution the products containing glass powder had a better density and a 10% replacement of the cement by the GP was more resistant than the conventional in GP.

The main objective of this study is to make a comparison between two types of ordinary and high performance concretes elaborated on the basis of different dosage in cement CPA without additions usually noted CEM I class 52.5, also at different ratio W/B by replacing a quantity of this cement by the glass powder with fineness of 3600 cm^2/g. A monitoring of the strength evolution is studied at different ages from 7 to 365 days to explain this GP substitution, cement dosing and the variation of the W/B ratio.

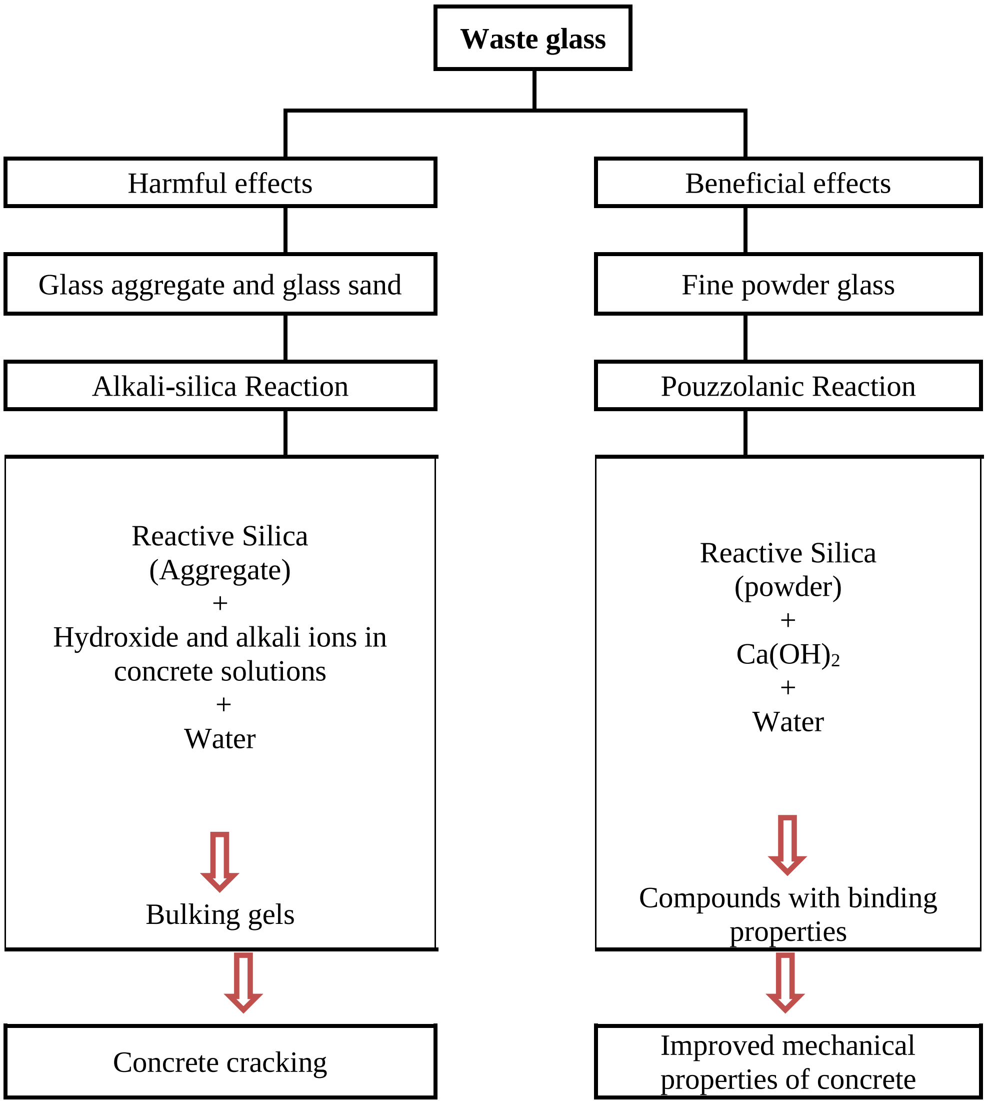


Fig. 1. Summary diagram illustrating the two reactions: alkali-silica and pozzolanic

MATERIALS AND METHODS

Cement

The used cement is the CPA Portland Cement noted CEM I 52.5 without any addition (95% clincker + 5% gypsum), produced by the Sour El Ghouzlane cement industrial group (GICA) located in the wilaya of Bouira (Algeria) and conforms to the norm NF EN 197-1 and ASTM C150 whose clinker is produced and crushed together with gypsum, which mineralogical composition as well as chemical composition and physico-mechanical characteristic of cement are presented respectively in Tables 1 and 2.

Table 1. *Chemical characteristics of cement and glass powder, physico-mechanical characteristic of cement*

Oxides (% by mass)	CEM I 52.5	Glass Powder	Physical characteristics of cement	
SiO_2	21.29	70.50	Initial setting time:	2h08min
Al_2O_3	4.72	1.42	Initial setting time:	5h13min
Fe_2O_3	3.49	0.10	Specific gravity:	3.47
CaO	64.68	8.43	kg/m^3	
MgO	0.44	4.01	SSB :	2530
Na_2O	0.17	15.28	cm^2/g	
SO_3	2.06	0.25	Normal consistency (%):	25.8
Loss on ignition	1.93	0.22	Compressive strength (MPa)	
			7 d:	45
			14d:	50
			28d:	56

Table 2. *Mineralogical composition of cement CEM I*

Constituents	C_3S	C_2S	C_3A	C_4AF	gypsium
Percentage (%)	60.61	15.36	6.6	10.61	5

Glass powder

The glass powder is obtained by selecting only the green and white bottles, cleaned to remove the paper labels, dried, crushed and finely ground with a specific surface area of 3600 cm ^{2}/g. The chemical composition is done using X-ray fluorescence (XRF) and particle size curve and distribution analysis of the glass powder are shown in Table 1 and Figures 2 and 3 by using Particle size lazer analysis that studies the particle size distribution in dry powder samples, with the principle of laser diffraction using the principle of diffraction and scattering of a laser beam hitting a particle. Particles pass through a fixed laser beam. Each particle diffracts light at an angle that is dependent on its size. The diffracted light is collected by a multi-element detector then the diffraction image obtained is transformed using an appropriate optical model and mathematical procedure. Finally, the result, illustrated as a semi-logarithmic curve, is a particle distribution in volume. The results reveal that the granulometric distribution is between 0.832 µm and 600 µm, the maximum particle size recorded is about 600µm and more than 60% of glass powder particles used have diameter less than 100 µm that the maximum particle size recorded of GP is about 120 µm (see Fig. 3)

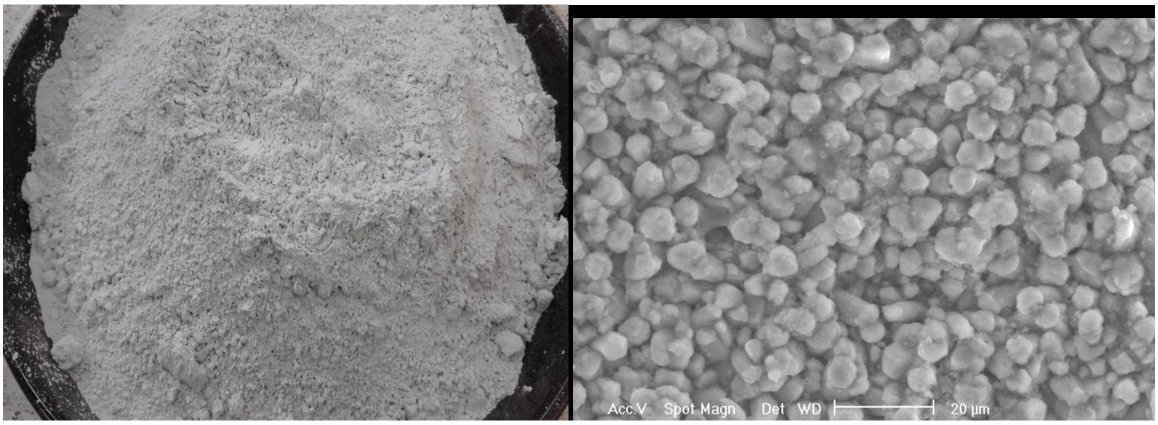
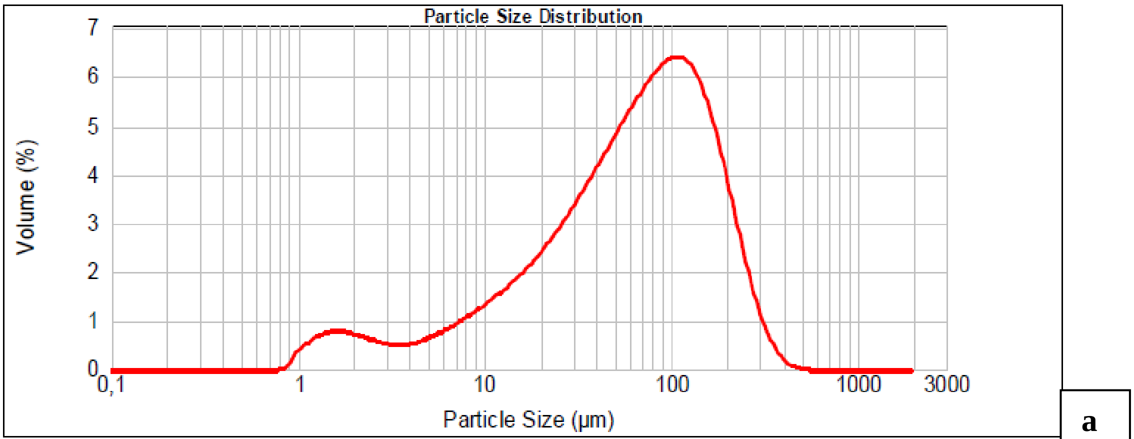


Fig. 2. The glass powder and his MEB image

Concentration: 0,0047 %Vol | **Span :** 2,666 | **Uniformity:** 0,836 | **Result units:** Volume

Specific Surface Area: 0,36 m²/g | **Surface Weighted Mean D[3,2]:** 16,675 um | **Vol. Weighted Mean D[4,3]:** 84,322 um

d(0.1): 8,643 um | **d(0.5):** 66,153 um | **d(0.9):** 185,018 um



Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %	Size (µm)	Volume In %
0,010	0,00	0,105	0,00	1,096	0,54	11,482	1,44	120,226	5,64	1258,925	0,00
0,011	0,00	0,120	0,00	1,259	0,66	13,183	1,62	138,038	5,23	1445,440	0,00
0,013	0,00	0,138	0,00	1,445	0,71	15,136	1,82	158,489	4,58	1659,587	0,00
0,015	0,00	0,158	0,00	1,660	0,71	17,378	2,04	181,970	3,72	1905,461	0,00
0,017	0,00	0,182	0,00	1,905	0,66	19,953	2,29	208,930	2,80	2187,762	0,00
0,020	0,00	0,209	0,00	2,188	0,59	22,909	2,57	239,883	1,89	2511,886	0,00
0,023	0,00	0,240	0,00	2,512	0,52	26,303	2,87	275,423	1,14	2884,032	0,00
0,026	0,00	0,275	0,00	2,884	0,48	30,200	3,20	316,228	0,58	3311,311	0,00
0,030	0,00	0,316	0,00	3,311	0,46	34,674	3,55	363,078	0,26	3801,894	0,00
0,035	0,00	0,363	0,00	3,802	0,49	39,811	3,91	416,869	0,08	4365,158	0,00
0,040	0,00	0,417	0,00	4,365	0,54	45,709	4,27	478,630	0,02	5011,872	0,00
0,046	0,00	0,479	0,00	5,012	0,63	52,481	4,63	549,541	0,00	5754,399	0,00
0,052	0,00	0,550	0,00	5,754	0,74	60,256	4,98	630,957	0,00	6606,934	0,00
0,060	0,00	0,631	0,00	6,607	0,86	69,183	5,30	724,436	0,00	7585,776	0,00
0,069	0,00	0,724	0,00	7,586	0,99	79,433	5,57	831,764	0,00	8709,636	0,00
0,079	0,00	0,832	0,09	8,710	1,13	91,201	5,75	954,993	0,00	10000,000	
0,091	0,00	0,955	0,39	10,000	1,28	104,713	5,80	1096,478	0,00		
0,105		1,096		11,482		120,226		1258,925			b

Fig. 3. Particle size lazer analysis. a- particle size curve, b- distribution of glass powder

Aggregates

A mixtures of two different kind sands, fine sand of Boussaâda (Algeria) having 6.6% of the total mass and the second is crushed, natural limestone rock of Sidi Slimane region of 93.4% of total mass while final fineness modulus after homogenization is 2.60. Gravels are crushed aggregates of the same mineralogical nature as crushed sand, the principal characteristics of the used aggregates are given in Table 3 and the results of the particle size aggregates analysis by dry method according to the NF EN 932-2 standard are represented in Figure 4.

Table 3. *Physical characteristics of aggregates*

Charactéristics	Sand	Gravel 3/8	Gravel 8/15
Absolute density (g/cm^3)	2.7	2,63	2,77
Bulk density (g/cm^3)	1.6	1,42	1,38
Porosity	/	1,05	1,50
Absorption	/	0,42	0,13
Module of fineness	2.6	/	/
d/D	0/4	3/8	8/15

Admixtures SP and water mixture

Ordinary clean water free from suspended particles and chemical substances was used for both mixing and curing concretes. A water-reducing plasticizer of SIKA VISCOCRETE TEMPO 12 in accordance with NF EN 934-2 is used as admixture with 2% of cement mass, it allows to keep a long rheological maintaining (>2H) it improves the stability and decreases segregation risks. The recommended proportion is 0.1–5% of cement weight according to the desired performances.

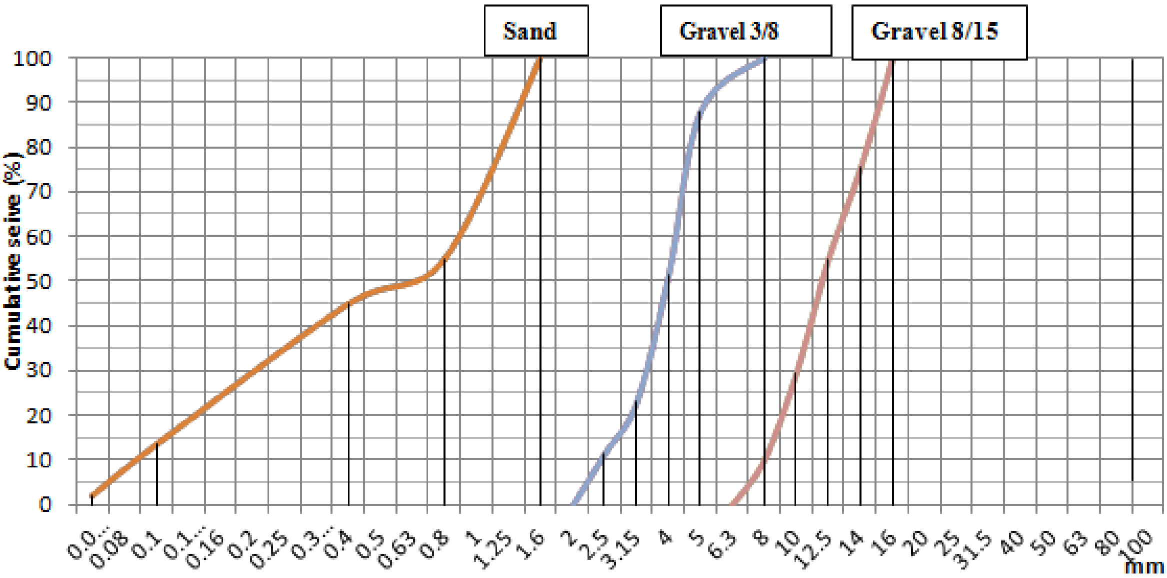


Fig. 4. Dry sieve analysis of aggregates NF EN 932-2

Formulation of concretes

Two types of concrete have been formulated one ordinary OC and the other has high performance HPC, the parameters to vary are:

1- Dosing in cement 400 kg/m^3 and 450 kg/m^3

2- Percentage of glass powder 10 and 20% replacement of cement mass

3- Variation of the ratio W/B, or B=C+GP with 0.35 and 0.5 where B represents the binder which is equal to the sum of the cement and the glass powder.

In order to verify, understand and explain the effects of glass powder on the properties of concretes based cement CEM I without additions a control concrete with 0% GP without glass powder addition was formulated as reference. The various concrete compositions are summarized in Table 4.

The specimens were prepared according to the standard NF P 18-400, the mixing of the concrete is carried out in a cement mixer with a capacity of 30 liters. The glass powder is mixed with the cement alone and dumped at the same time, without any precaution and at random. The total mixing time 5min (1 minute of dry mixing and 4 minutes of wet mixing). Compaction was carried out on a vibrating table for one minute. After 24 hours storage of the molds in open air, the specimens were demoulded and stored in a tank of fresh water under laboratory condition at 25 °C (saturating humidity (HR = 100%) and an ambient temperature).

For a better understanding, the following abbreviations are used with detail of the composition in the Table 4:

HPCR: High performance concrete reference with 0% GP replacement of Cement C and W/B=0.35

HPC10: High performance concrete with 10% GP replacement of Cement C and W/B=0.35

HPC20: High performance concrete with 20% GP replacement of Cement C and W/B=0.35

OCR: Ordinary concrete reference with 0% of GP replacement of Cement C and W/B=0.5

OC10: Ordinary concrete reference with 10% of GP replacement of Cement C and W/B=0.5

OC20: Ordinary concrete reference with 20% of GP replacement of Cement C and W/B=0.5

Table 4. *High performance and ordinary concrete compositions*

	Unit	HPCR	HPC10	HPC20	OCR	OC10	OC20
% de GP	%	0	10	20	0	10	20
Cement C	kg/m^3	450	405	360	400	360	320
GP	kg/m^3	0	45	90	0	40	80
Water	l/m^3	157.5	157.5	157.5	200	200	200
W/B*	/	0.35	0.35	0.35	0.5	0.5	0.5
W/C**	/	0.35	0.38	0.43	0.5	0.55	0.62
Sand	kg/m^3	602	602	602	624	624	625
G 3/8	kg/m^3	210	210	210	215	215	215
G 8/15	kg/m^3	995	995	995	1017	1017	1017
SP	l/m^3	9	9	9	6	6	6

GP: Glass Powder *B: binder, B=C+GP **C: cement

RESULTS AND DISCUSSION

Fresh properties

Abrams cone test method explained in **[17]** consists in measuring the slump height of a truncated cone-shaped volume of fresh concrete. Slump test was carried out according to standard NF P 18-451**,** see Figure 5.

Figure 6 shows the variation of the Abrams cone slump of the concretes according to glass powder percentage variation and the W/B ratios used.

Fig. 5. Slump test with Abrams cone

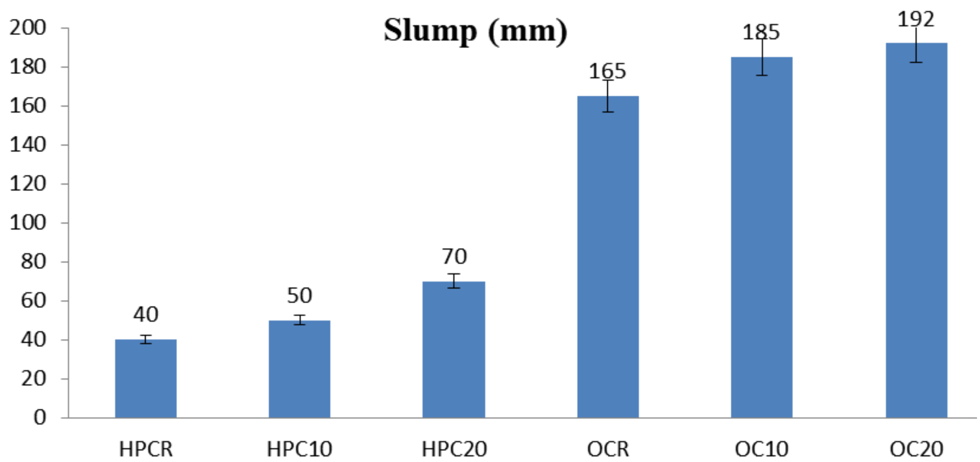


Fig. 6. Slump variations of all concretes

There is an increase in the workability of all concretes with the increase in the percentage of glass powder for both W/B ratios of either 0.35 or 0.5, this is due on the one hand to the substitution of the cement part by the glass powder variation of fineness compared to the HPCR and OCR, so the used addition is finely ground so it fills the pores and releases the trapped water since the W/C.

Another explanation for workability increasing with increasing GP content is cement dilution, which tends to reduce the formation of cement hydration products in the first few minutes of mixing. Therefore, there are insufficient products to bridge various particles together **[24].** In addition, the cement used in this study had a specific surface area less than that of the GP, therefore, the total surface area of the cement and GP blend decreased when using GP as cement replacement. Consequently, the water demand to lubricate particle surfaces decreased due to the drop in the net particle surface area, and hence the slump flow for the same W/B.

Nevertheless it is clear that the subsidence of the three ordinary concretes (OCR, OC10, OC20) formed with a dosage of 400 kg/m^3 and a W/B equal to 0.5 is greater than those of the high performance concretes formed with a greater dosage and less quantity of water, reflection made that the glass powder with the use fineness can of water demand. Also BHPR, BHP10 and BHP20 can be widely classified in the range of firm concretes and as being OCR,OC10, OC20 of plastic concrete seen the results of Figure 6.

The more the W/B ratio is reduced the more viscous the concrete is and requires vibration, the fluidity of concrete is increased with the use of glass powder, due to their small spherical particles and their huge specific surface that can fill the gap between the cement grains instead of it being occupied by water and usually causes a reduction in the amount of water required for workable concrete [24].

Hardened properties

The hydraulic press with maximum capacity of 3000 kN is used in order to evaluate compressive strength of cylinder (11 × 22) cm dimensions and the flexural tensile tests are determined on prismatic specimens (7 × 7 × 28) cm^3 according to the standard NF EN 12390-3 (Fig. 7).

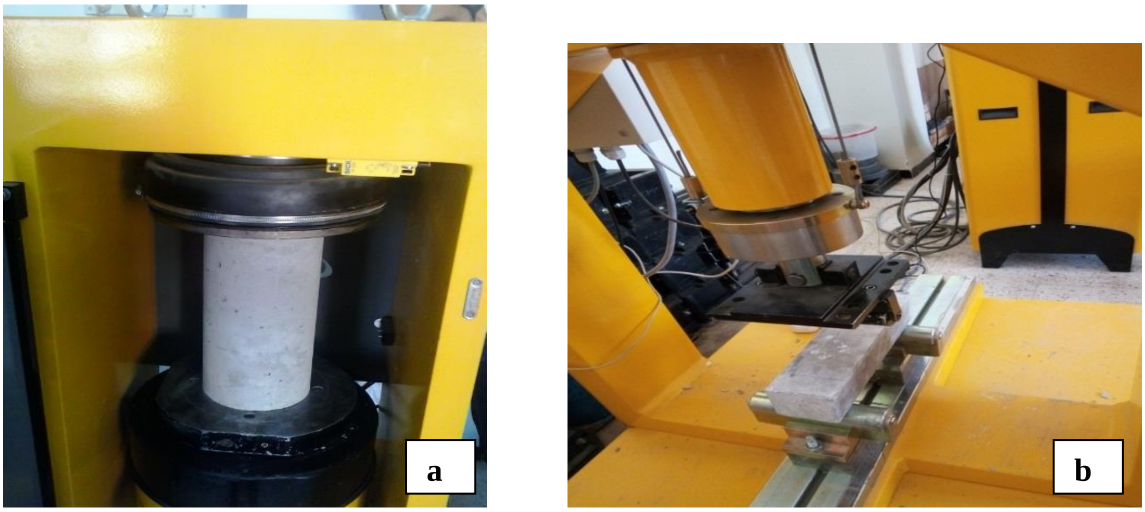


Fig. 7. a- Compressive test cylinder (16 × 32) cm b- 3 point flexural test prismatic (7 × 7 × 28 cm^3)

The kinetics of development strength of different concretes according to the dosage of glass powder over time is presented in Figure 8.

A trend can be observed in concretes with the ratio W/B=0.5 is that the pozzolanic reaction of glass powder is slower at young age (7 and 28 days) but tends to develop later in time (365 days) as shown in Figure 8. Until 28 days, the compressive strength of concretes with glass powder increased OC10 and OC20 at 365 days to even exceed the strength of OCR (51.8MP A), which is explained by the pozzolanic reaction, these results are consistent with previous studies where it is noted that the resistances of ordinary concretes incorporating glass powder develop over time [25, 26]. This delay in the development of compressive strength in OC at young age containing glass powder for the ratio W/B=0.5 is due to an insufficient amount of portlandite produced by the hydration of cement replaced by an amount of GP and free water can promote an optimal continuation of the pozzolanic reaction of glass powder.

For the ration W/B=0.35, HPC there is a completely opposite behavior compared to OC such as a positive progression of compressive strength as a function of the time and the substitution rate of the GP; the HPC10 and HPC20 always remain superior to HPCR at any age, where it can be said that the formation of beneficial binding properties for concrete (Poozolanic reaction) are affected by the amount of water, they appear from early age when the amount of water is reduced in the presence of glass powder. The results of compressive strength at 365 days therefore suggest that a dosage of 20% GP gives the best results obtained (68.3 MPa) in the experimental conditions tested with cement without additions of class CEM I 52,5 working with the ratio W/B or B represents in our case cement + glass powder.

Other authors [17] have obtained compressive strength of 32MPa for 20% GP with cement class CEM II 42.5 working with W/B ration equal to 0.5, where the effect of glass powder therefore depends on the strength class of the cement to which it is substituted and fineness.

For the effect of the ratio, the three concretes formulated with the ratio W/B=0.35 have higher compressive strengths than those of the three concretes formulated with the ratio W/B= 0.5, the largest deviation of strength is 14 MPa recorded between HPC20 and OC20. The use of superplasticizer SP (water reducers) allows the reduction of the W/B ratio by opposing the flocculation of cement grains (SP=9 l/m^3 for HPC and SP=6 l/m^{3}for OC), so our concretes have a conventional granular skeleton embedded in an increased compactness matrix. Which results that the amount of water removed in the formulation of HPC with W/B= 0.35 was replaced by the increase of the amount of SP to 9 l/m^3 (see table 4)

Indeed, compared to [25] which combined glass powder with other additions such as silica smoke and limestone filler in the formulations of self-lacing concretes concluded that: some additions have a high water demand compared to the load of chemically inert limestone, which can reduce the workability properties of concrete.

The ratio W/B = 0.35 means that the amount of water is very small compared to the mass of cement, the cement grains are very close to each other, the water will react with the cement grains and there will remain only very little capillary porosity, the permeability of the concrete will be very low and the mechanical properties of the concrete will be very high (68.3 MPa), which improves the durability at the age of 365day.

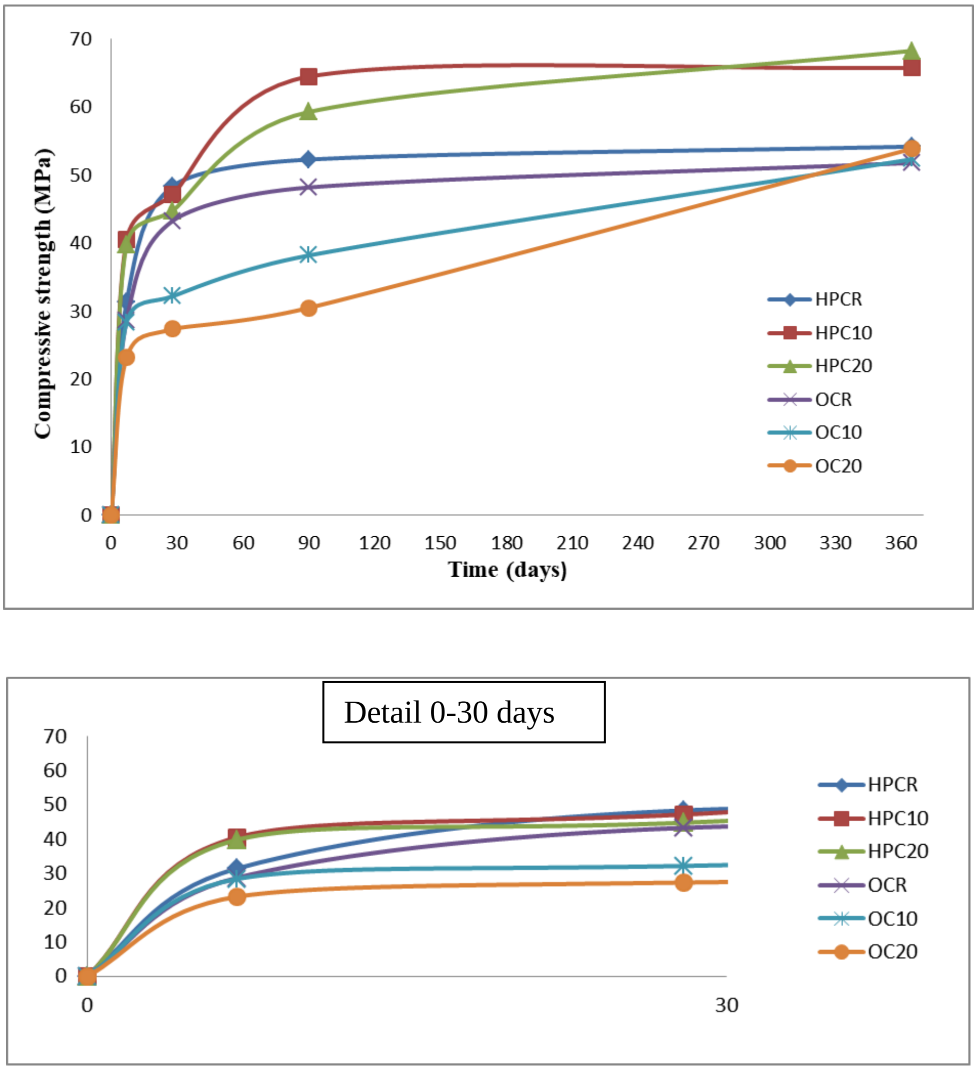


Fig. 8. The kinetics strength development of different concretes according to the dosage of glass powder over time

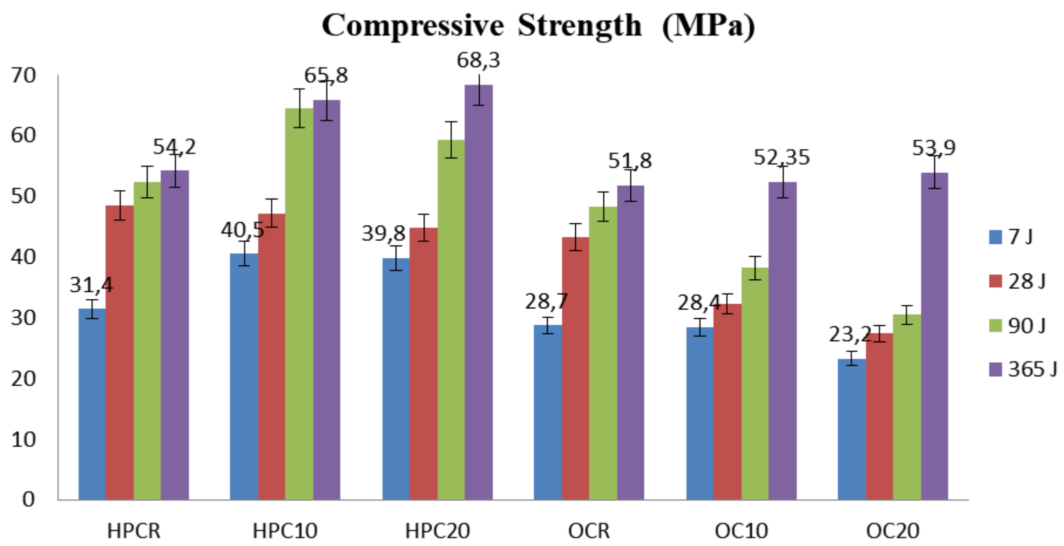


Fig. 9. Effect of Glass Powder on concretes compressive strength at different ages

Regarding to Figure 9, at 365 days of hardening, the results seem very interesting because a logical progression between the dosage in cement and the quantity of water of breakdown used, the behavior of HPC remains always better compared to OC and the strength is more concrete with GP remains also better than those of reference. Although the compressive strength of concrete HPC 20 noted at 68.3 MPa with a quantity of cement 360 Kg/ m^3 is better than that of concrete OC10 of 52.35 MPa with the same dosage of cement 360 Kg/ m^3 which shows a strength gain of 16 MPa, which are advantageous for the HPC manufacture.

According to ASTM C618, the mineralogical characterization of the glass powder shows that the sum Al_2O_3 + SiO_2 +Fe_2O_3 = 74.2% > 70% (see Table 1), the allowed us to conclude that this glass powder is a pozzolanic material, also the compressive strength improvement can be explained by the chemical and physical effect exerted by GP according to the work of **[7]** by the formula :

$$\text{Pouzzolan + lime + water} \longrightarrow \text{Calcium Silicate Hydrate (C-S-H)}$$

Since its high content of amorphous silica SiO_2 gives it pozzolanic properties by combining with lime containing in the cement to produce other hydrates such as in the presence of water associated with the temperature released by the hydration of the cement Portland C_2S and C_3S (see table 2) they combine to form hydraulic binders:hydrated calcium silicates (C-S-H) similar to those formed during hydration of Portland cement [27].

$$3CaO + SiO_2 + H_2O \longrightarrow CSH + Ca\,(OH)_2 \qquad \text{Cement hydration reaction}$$
$$CaO + SiO_2 + H_2O \longrightarrow CSH \qquad \text{Pozzolanic reactions}$$

Referring to the two previous reactions, it is clear that the pozzolanic reaction consumes calcium hydroxide or portlandite Ca (OH)2 to form hydrated calcium silicate (C-S-H). We took care to keep the test tubes in water because at room temperature, this reaction is generally slow and can develop over several weeks, the main goal of our research to collect the results after 365 days of storage. However, according to research by [28], the thinner and glassy the pozzolan, the faster it reacts with lime and its water demand depends on its fineness.

With fineness of 3600 cm ^{2}/g, GP adjusts the granulometry of the cement CEM I without additions CEM I 52.5 with fineness of 2530 cm^2/g by physical filling, thus the paste compactness was increasing, and a pozzolanic reaction by chemical reaction with clinker products hydration to form dense hydrated calcium silicates C-S-H [7].

The compressive strength is controlled by the value of the ratio W/B, such as 0.35, the strength increases, who a reduction of 43 litres l/m^3 of mixing water (see Table 4) leads to an increase of 10 to 20% in the compressive strength. Figure 9 shows that the compressive strength of concrete increases as the W/B ratio decreases and the age of concrete increases.

The low compressive strength of the OC compared to the HPC with a replacement of 20% GP can be attributed to the voids formed between the GP grains given its vitreous and smooth surface non-absorbent to water, containing in CBs designed during the manufacture of ordinary concrete filled with water caused by the high ratio W/B=0.5, which weakened the development of a better resistance to compression, avoided in HPC with low W/B=0.35 resulting greater strength at 365 days.

CONCLUSIONS

The general objective of this work was to make a comparative study on the effect of the substitution of cement without additions CEM I 52.5 by glass powder (GP) finely ground to percentages of 10 and 20% of the cement mass on the mechanical strength of high performance HPC and ordinary OC concretes by varying the W/ B ratios thus the quantity of mixing water and the cement dosage.

1. For workability the HPC and OC have the same behavior screw to screw of the replacement of the cement by the GP, the maneuverability increases by increasing the amount of glass powder, it is reflected by the variation of the pasta specific surface thanks to the great fineness of the glass powder (3600 cm ^{2}/g) compared to the cements and therefore a decrease in demand for water. Nevertheless the results of the slump test show a divergence between the two concretes with respect to the quantity of water, the collapse decrease with the decrease of the ratio W/B, such that the HPC are firm concretes and OC are plastic concretes.
2. The glass powder, like other conventional cementitious additions and being poozolanic, modifies the kinetics of development of compressive strength of concretes, an opposite behavior between HPC and OC was concluded according to the results such as: a slow development of resistance at young age, the strength of OC10 and OC20 is lower than that of OCR without GP, an observation explained by the changes in hydration of the cementitious matrix induced by the substitution of cement by the GP which absorbs less water than cement, on the other hand, at 365 days of hardening, we observe that the addition of 10% or 20% of GP improves the compressive strength to exceed that of the OCR.
3. Concerning the HPC with the ratio W/B=0.35, the resistance to compression was more important for HPC10 and HPC 20 compared to HPCR without glass powder at any age, which explains why the glass powder with a fineness superior to that of the concrete CEM I 52.5 exerts a physical and chemical effect from early age to form the C-S-H with a limited quantity of water mixture, thus developing more in time to give the best results.
4. Even for an identical dosage in cement, the strength of HPC with GP remain better than those of OC, so a gain strength of 27% at 365 days is ensured by limiting the ratio W/B, then compressive strength of concretes increases as the W/B ratio decreases, age of concrete increases and percentage of glass powder increase.

Following the results obtained for compressive strength of HPC20 and OC20 compared to others concretes; the best rate of cement replacement with GP is 20%, which is about 14 MPa more than HPCR with cement quantities gain of 90 Kg/m^3, also this gain in mass and strength is beneficial for cement production company's who will save about 20% of their first used material during production as well as the builders during the preparation of the concrete formula.

Our future research will be based on the extension in terms of time for the compressive strength of this concrete based glass powder in the long term (concrete aged 3 years), as well as the study of the microstructure, without forgetting the passage through chemical durability in aggressive environments such as acids and sulfates to better consider its use in marine areas.

Conflicts of Interest

The authors declare that they have no competing financial interests or personal relationships that could have seem to influence the study reported in this paper.

REFERENCES

1. Jani Y, Hogland W. (2014). Waste glass in the production of cement and concrete – A review. Journal of Environmental Chemical Engineering, 1767–1773.
2. Aliabdo A A, Abd Elmoaty A E M, Aboshama A Y**.** (2016).Utilization of waste glass powder in the production of cement and concrete. Construction and Building Materials, 124. 867–875.
3. Nehar, K. C. and Benamara, D. (2021). Experimental study and modeling of the mechanical behavior of recycled aggregates-based high-strength concrete. Frattura ed Integrità Strutturale, 15(56): 203–216.
4. Mesboua, N, Benyounes K, Kennouche S, Ammar Y, Benmounah A, and Kemer H. (2021). Calcinated Bentonite as Supplementary Cementitious Materials in Cement-Based Mortar. Journal of Applied Engineering Sciences, 11 (1): 23-32.
5. Tayeh, Bassam A, Doha M Al Saffar, and Rayed Alyousef. (2020). The utilization of recycled aggregate in high performance concrete: a review. Journal of Materials Research and Technology, 9 (4): 8469-8481.
6. Marvila, Markssuel Teixeira, Jonas Alexandre, Afonso RG de Azevedo, and Euzébio Bernabé Zanelato. (2019). Evaluation of the use of marble waste in hydrated lime cement mortar based. Journal of Material Cycles and Waste Management, 21 (5): 1250-1261.
7. Hongjian D, Kiang H T. (2013). Use of waste glass as sand in mortar: Part II – Use of waste glass as sand in mortar: Part II – Alkali–silica reaction and mitigation methods. Cement Concrete Composite, 35: 118–126.
8. Limbachiya, M., Meddah, M S., Fotiadou, S. (2012). Performance of granulated foam glass concrete. Construction and Building Materials, 759-768.
9. Kiang H T and Du H. (2013). Use of waste glass as sand in mortar: Part I – Fresh, mechanical and durability properties. Cement & Concrete Composites, 35, pp. 109–117.
10. Khmiri, A., Samet, B., Chaabouni, M. (2012). Assessement of the waste glass powder pozzolanic activity by different methods. International Journal of Research Review in Applied Science, 10: 322-328.
11. Idir R, Cyr M, Tagnit-Hamou A. (2010). Use of fine glass as ASR inhibitor in glass aggregate mortars, Construction and Building Materials, 24: 1309 –1312.
12. Idir, R., Cyr, M., Tagnit-Hamou, A. (2011). Potential pozzolanicity of glass cullet fines and aggregates. Annales du Bâtiment et des Travaux Publics, 28-34.
13. Bhandari, P S and Tajne, K M. (2013). Use of waste glass in cement mortar. International Journal of Civil and Structural Engineering, 3: 704-711.
14. Matos, A M., Sousa-Coutinho, J. (2016). Waste glass powder in cement: Macro and micro scale study. Advances in Cement Research, 28 (7): 423-432.
15. Sadiqul Islam, G M., Rahman, M H., Kazi, N. (2017). Waste glass powder as partial replacement of cement for sustainable concrete practice. International Journal of Sustainable Built Environment, (6): 37–44.

16. Redden R, Neithalath N. (2014). Microstructure, strength, and moisture stability of alkali activated glass powder-based binders. Cement and Concrete Composites, 45:46-56.
17. Boucheneb Y, Mehaddene R, Kemer H. (2023). Experimental characterization of the mechanical properties of concrete based on glass-powder. Journal of Applied Engineering Sciences, 13(26): 27-38.
18. Belouadah, M., Rahmouni, Z.E.A and Tebbal, N. (2018). Effects of glass powder on the characteristics of concrete subjected to high temperatures. Advances in Concrete Construction, 6(3): 311-322.
19. Adil Sultan M, Jawad M, Muzffar Iqbal M, Ghafoor I, Farooq U, Din U S and Mushtaq A. (2023). A comparative study: Effects of fineness of cement on consistency and compressive strength of different branded cement in Pakistan. Journal of Applied Engineering Sciences, 13(26): 9 – 16.
20. Khattab M, Hachemi S, benzett H. (2022). Effects of cement quantity on the behavior of recycled concrete aggregates.1st International Conference on Innovative Academic Studies. Konya, Turkey.
21. Merabti S. (2022). Effect of concrete class, maximum aggregate size, and specimen size on the compressive strength of cores and cast specimens. Advances in Materials Science, 22(4): 21-31.
22. Amin M, Saad Agwa I, Mashaan N, Mahmood S, Mahmoud H. (2023). Investigation of the Physical Mechanical Properties and Durability of Sustainable Ultra-High Performance Concrete with Recycled Waste Glass Abd-Elrahman. Sustainability, 15(4), 3085.
23. Almeshal I, Al-Tayeb M M, Qaidi S M A, Abu Bakar B H, Tayeh B A. (2022). Mechanical properties of eco-friendly cements-based glass powder in aggressive medium. Materials Today: Proceedings, 58(4): 1582-1587.
24. Behim M, Boucetta T. A. (2013). Valorisation du verre à bouteille comme addition fine dans les bétons autoplaçants. Déchets Sciences et Techniques, 65: 20-28.
25. Zidol A. (2014) Durabilité en milieux agressifs des bétons contenant de la poudre de verre. Thèse de Doctorat, Université de Sherbrooke, Canada, 234.
26. Adaway M, Wang Y. (2015). Recycled glass as a partial replacement for fine aggregate in structural concrete – Effects on compressive strength. Electronic Journal of Structural Engineering, 14(1): 116 – 122.
27. Chekireb S. (2015). Valorisation de la poudre de verre dans le béton autoplaçant. University of Sherbrooke.
28. Shao Y, Thibaut L, Shylesh M, and Damian R. (2000). Studies on concrete containing ground waste glass. Cement and Concrete Research 30 (1): 91-100.