



THE GLASS WASTE AS FINE AGGREGATE AND POZZOLANA ADDITION IN CONCRETE

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ISCOWA „Sustainable Management of Waste and Recycled Materials in Construction”

INTRODUCTION (1)

Objective - Problematic

- The valorization of the granular glass wastes in concrete as secondary raw material (SRM) – pozzolana and fine aggregate.
 - *Problematic of waste glass SRM*: high potential to produce an alkali-silica reaction (ASR), between the cement alkali and the reactive silica from the glass particles.
 - *The research focused on*: the potential concrete damage as an effect of the ASR associated expansion using different experimental scenarios.
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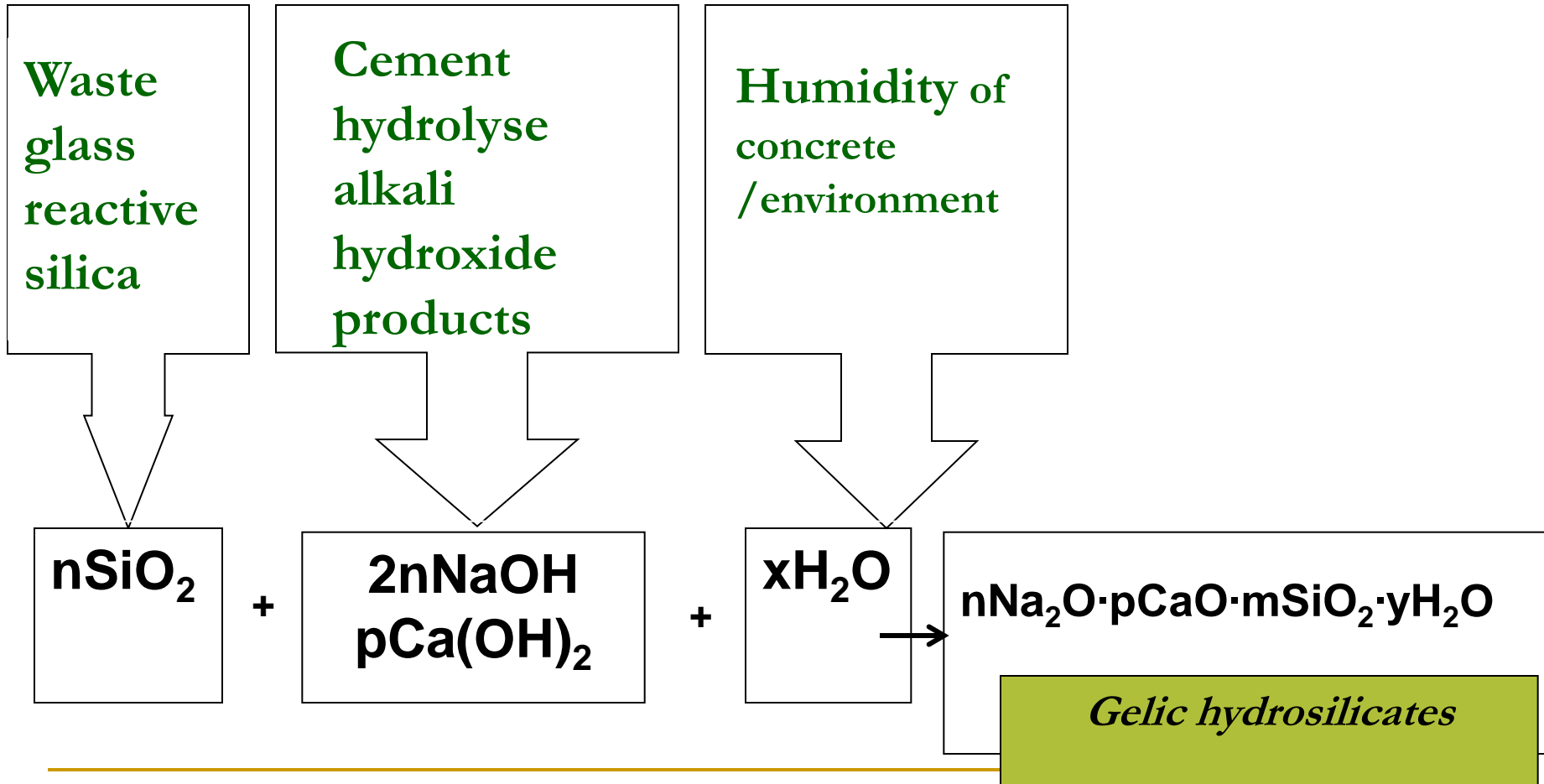
INTRODUCTION (2)

Alkali-silica reaction (ASR)

- The ASR products are gelic alkali hydrosilicates.
 - The high capacity of water absorption of hydrosilicates gel compounds is the main involved characteristic.
 - This phenomena causes swelling following by internal stresses development and concrete matrix cracking.
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INTRODUCTION (3)

Alkali-silica reaction (ASR):



MATERIALS (1)

Glass wastes - with lower and with higher alkali content

The oxide composition of some vitreous hydraulic active materials (pozzolana)

Material	SiO ₂	Al ₂ O ₃	B ₂ O ₃	CaO	MgO	Na ₂ O+K ₂ O
E glass	54.5	14.5	8.5	17	4.5	0.6
Soda-lime-silicate glass (packing)	74	1		9	0.7	14.5
Fly ash	51	24.2		8.3	2.3	2.8
Granulated blast slag	32	5		40	6	-

(Na₂O + K₂O) content of 0.6% and 14.5%, premise of the alkali –silica reaction (RAS) potential.

MATERIALS (2)

Concrete components:

- ❑ CEM II/A-S 32,5R and CEM III/A 32,5R (EN 197-1) with a smaller alkali content, and favorable influence of diminish ASR potential;
- ❑ Siliceous 0/4 mm river sand and 4/8 mm coarse aggregate;
- ❑ Glass waste;
- ❑ The limestone filler;
- ❑ High-range water reducer- HRWR /superplasticiser based on polycarboxylated ethers.

METHODS (1)

Testing of the glass waste alkali-silica reaction

- ***Sampling:*** mortar bars with the natural sand (as control) and with E glass or packaging glass waste sand.
 - ***Experimental conditions:*** 24 hours cured in a fog box at 25°C: initial length L_0 and cured at 90% R. H. and 38°C of 1, 2, 3, 6, 9 and 12 months - length L_i was measured;
 - ***Results:*** as length variation of bars as $\varepsilon_1 = (L_i - L_0)/L_0$.
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METHODS (2)

The concretes with addition of various glass waste particle size distribution and quantity

- ***The first group, G,*** with glass particles size distribution of 2- 8 mm, and cement CEM II /A-S 32.5 R.
- ***The second group, GA,*** with glass particles size distribution < 1 mm, with CEM III /A 32.5 R.

- ***The particle < 0.125 mm*** content of the concrete mixes was calculated and appreciated as a pozzolana;
- ***The binder*** was appreciated as cement + < 0.125 mm glass particles.

CONCRETE MIX (1)

Concrete mixes (G) with ground glass waste, partial and total substitute of the natural aggregate (*weight ratios*)

Concrete code	CEM II/A-S	Natural aggregate			Grounded glass waste			W/C ratio
		particle size, mm			particle size, mm			
		0/1	1/2	2/8	0/1	1/2	2/8	
R control	1	1.43	1.3	2.23	0	0	0	0.49
G5	1	0	0	2.23	1.43	1.29	0	0.56
G10	1	0	0	0	1.43	1.29	2.23	0.67

CONCRETE MIX (2)

Concrete mixes (GA) with glass waste sand (*weight ratios*)

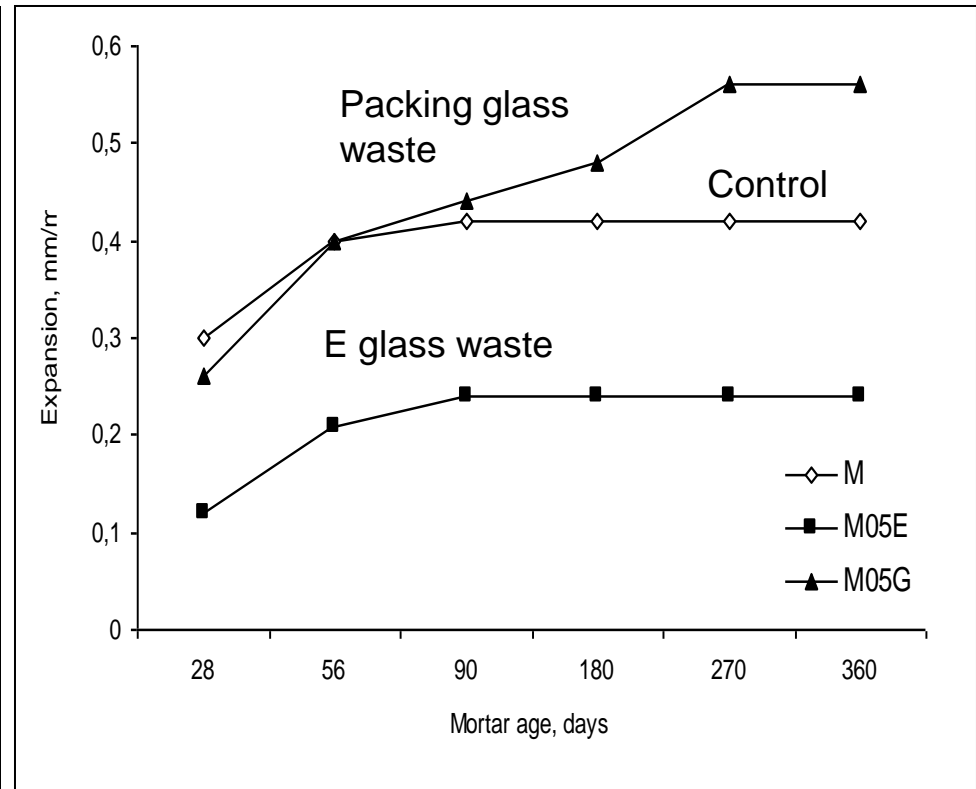
Concrete	CEM III/A 32.5R	Limestone filler	Grounded E glass waste			River sand			Coarse aggregate
		mm	mm			mm			mm
		<0.25	<0.25	0.25/ 0.5	0,2/1	0.25/ 1	0.5/ 1	1/4	4/8
A (control)	1	0,27	0	0	0	0.83	0	0.9	1.54
GA3	1	0	0.3	0	0	0.83	0	0.9	1.54
GA1	1	0	0.4	0.4	0.5	0	0	0.89	1.42
GA2	1	0	0.4	0.4	0	0	0.53	0.89	1.42

RESULTS AND DISCUSSIONS (1)

The ASR associated expansion measured on mortar bars

The 360 days-expansion of the mortar bars the with E glass waste showing the smallest values, as following some reasons:

- The lowest alkali equivalent content (Na_2O) of 0.6%, - E glass, versus 14.5% -package glass.
- The E glass high content of silica+alumina (of 69%), can inhibit the ASR expansion due pozzolanic activity of the fine particles.



The type sand $d < 0.5 \text{ mm}$, influence on the mortar bars expansion, associated to ASR.

RESULTS AND DISCUSSIONS (2)

The volume changes of concretes with glass waste addition

- The G concrete prisms with total aggregate of 0...8 mm particle size, substituted with E glass waste, present an important volume increase;
 - The GA concrete prisms with finer glass waste particles, <1 mm, are showed lower lengths variation.
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RESULTS AND DISCUSSIONS (2)

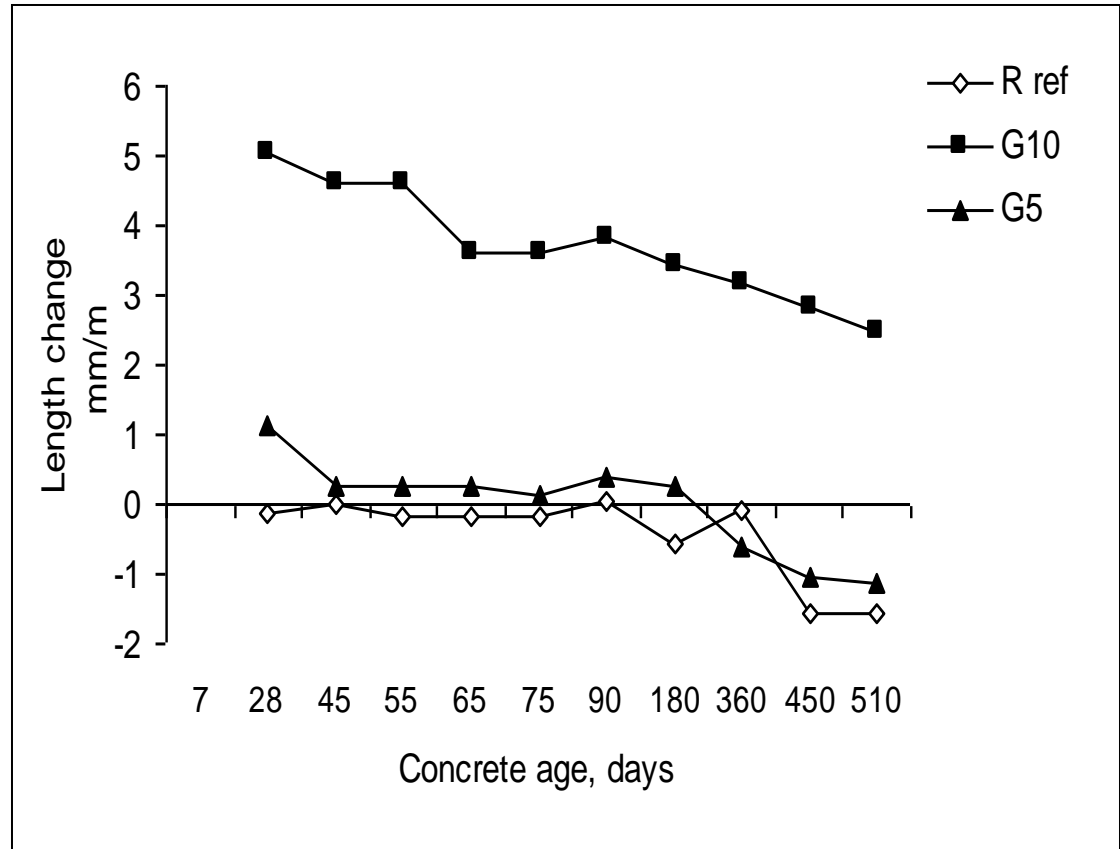
The length changes of G concretes with glass waste:

Significant expansion of G10 prisms:

- E glass waste as total aggregate of 0/8 mm;
- 100% natural aggregate substitution

The lower length change of G5 concrete with 0/2mm as glass fine aggregate:

- 50% natural aggregate substitution.



The linear deformation of G concrete prisms

RESULTS AND DISCUSSIONS (2)

The length changes of GA concrete with glass waste:

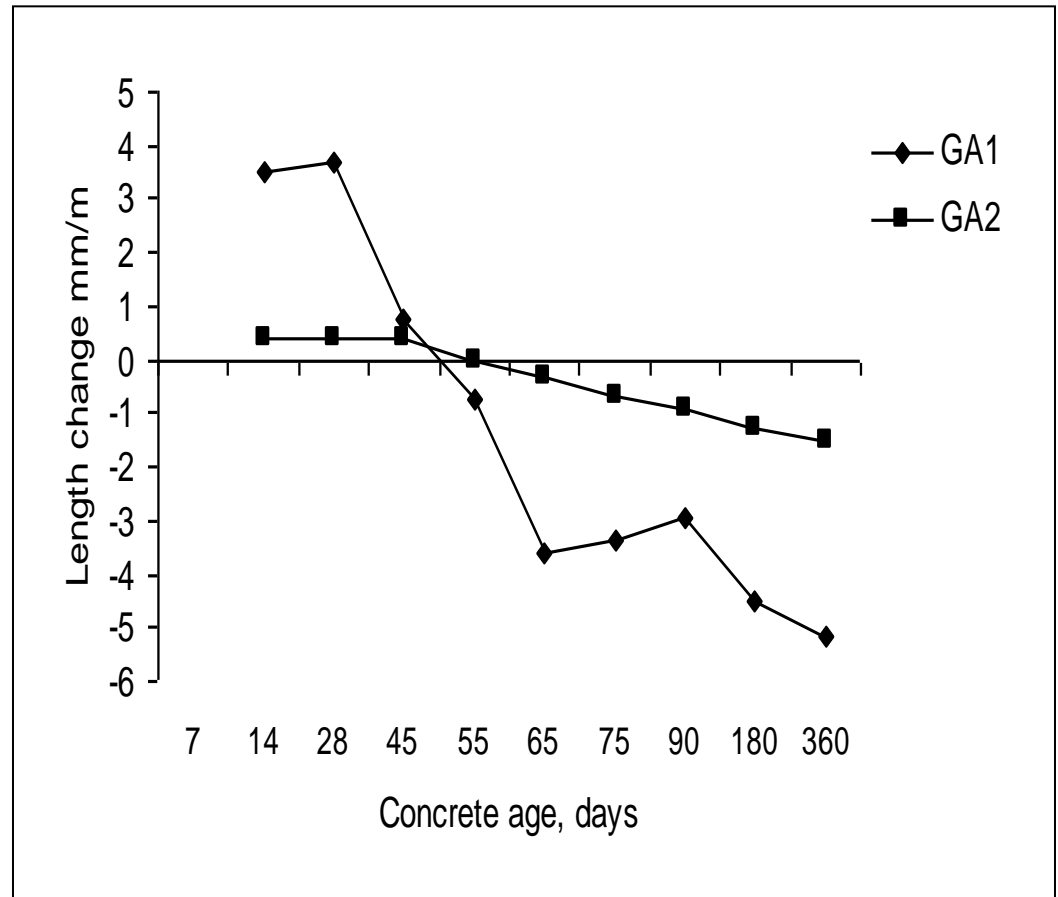
□ The glass waste particle size/total sand substitute:

✓ 1 mm/58%— GA1

✓ <0.5mm/33% -GA2

□ The <0.5 mm glass particle size doesn't induce ASR expansion of 360 days age-concrete.

□ The tendency of the time-shrinkage concrete.



The length change of GA serie concrete

RESULTS AND DISCUSSIONS (3)

The mechanical strength of the concretes with glass waste addition

Influence modes emphasized :

- *the maximum size and the amount of E glass particles at same level concrete mix W/C ratio;*

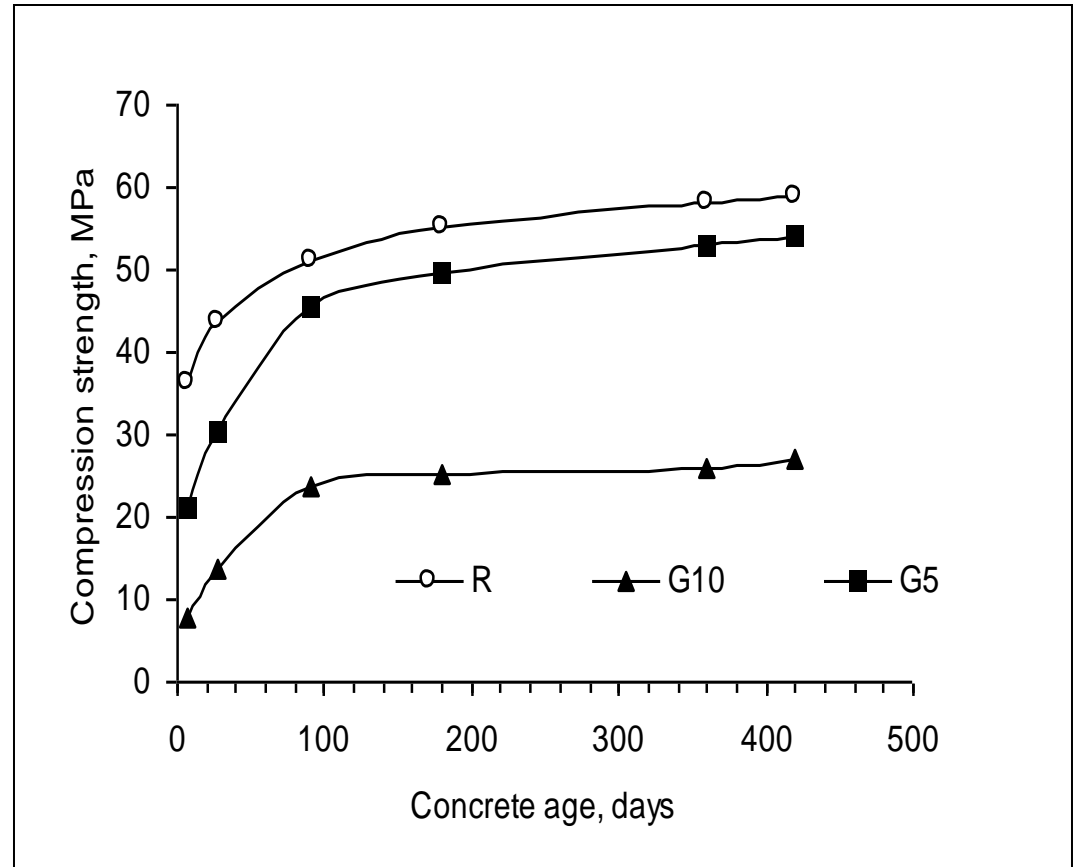
- *the concrete's age;*

- *stress type (compressive or bending).*

RESULTS AND DISCUSSIONS (3)

The compression strength of G concretes:

- The 28days-and the 420 days-compression strengths of G5 was 70% and 92% of the reference one.
- The 420 days-compression strengths reaches the value of 50-60MPa.
- The lowest compression strength of G10 with 100% glass particles as aggregate.

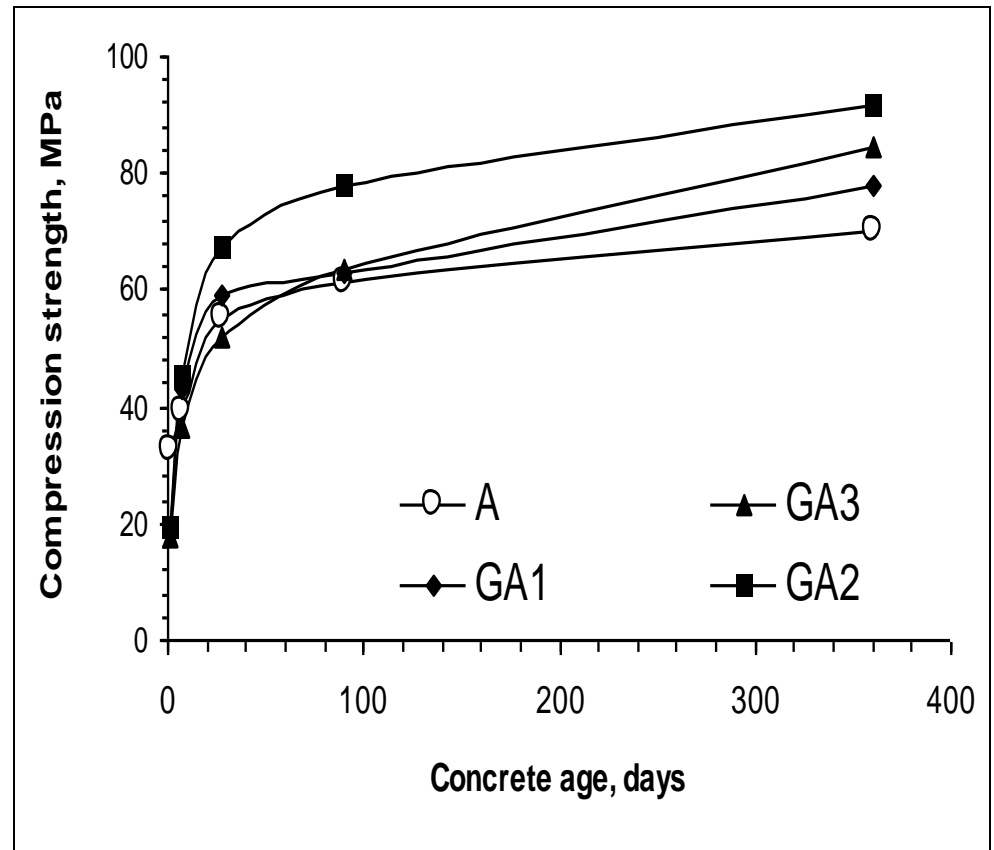


The compression strength of G concretes.

RESULTS AND DISCUSSIONS (3)

The GA concretes compression strength:

- The GA concretes compression strength continuously increased from 7 to 360 days;
- The later evolution are better than of control one due to pozzolanic character of the glass particles .
- The best compression strength of GA2 concrete with <math><0.5\text{ mm}</math> glass particles as 33 % wt. sand substitute.



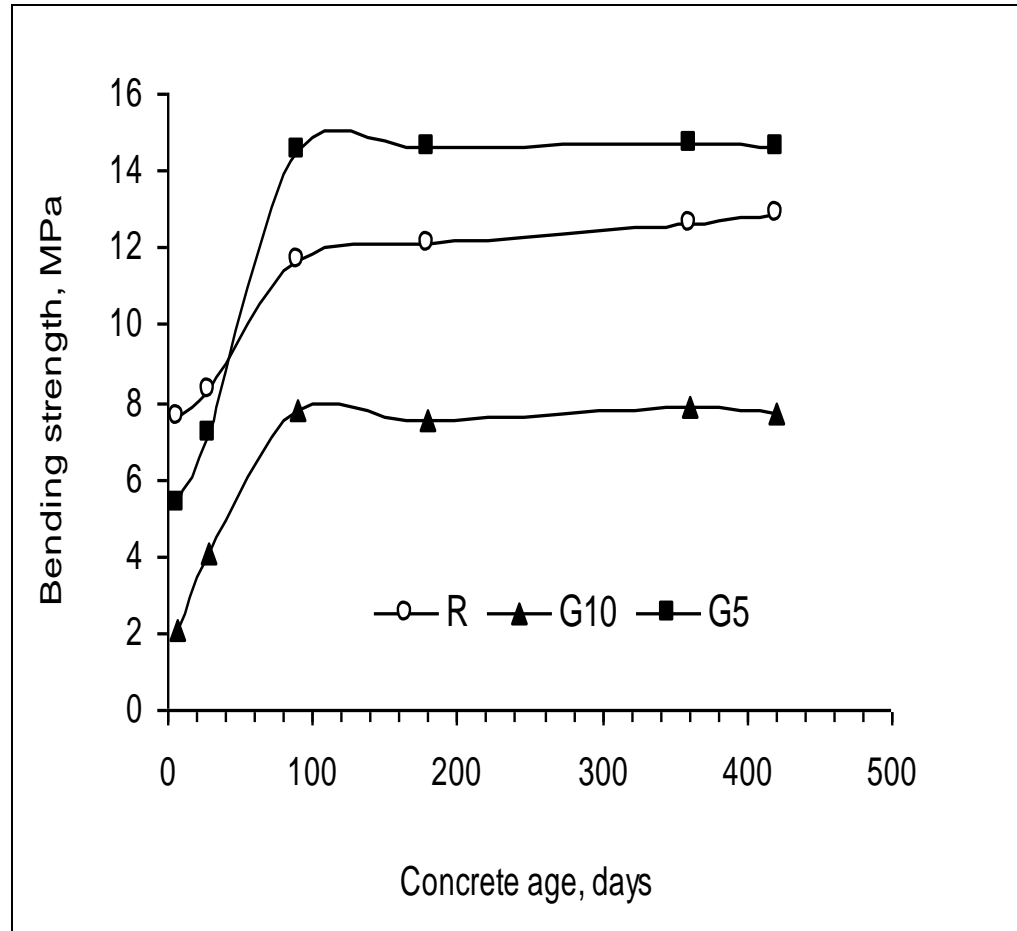
The compression strength of GA concretes

RESULTS AND DISCUSSIONS (4)

The bending strength of G concretes:

- The new hydrosilicates as products of the pozzolanic reaction close or interrupt ASR expansion microcracks of the matrix;
- This aspect can offer an explanation why the later age-bending strength of G5 was greater than of the R, control one.

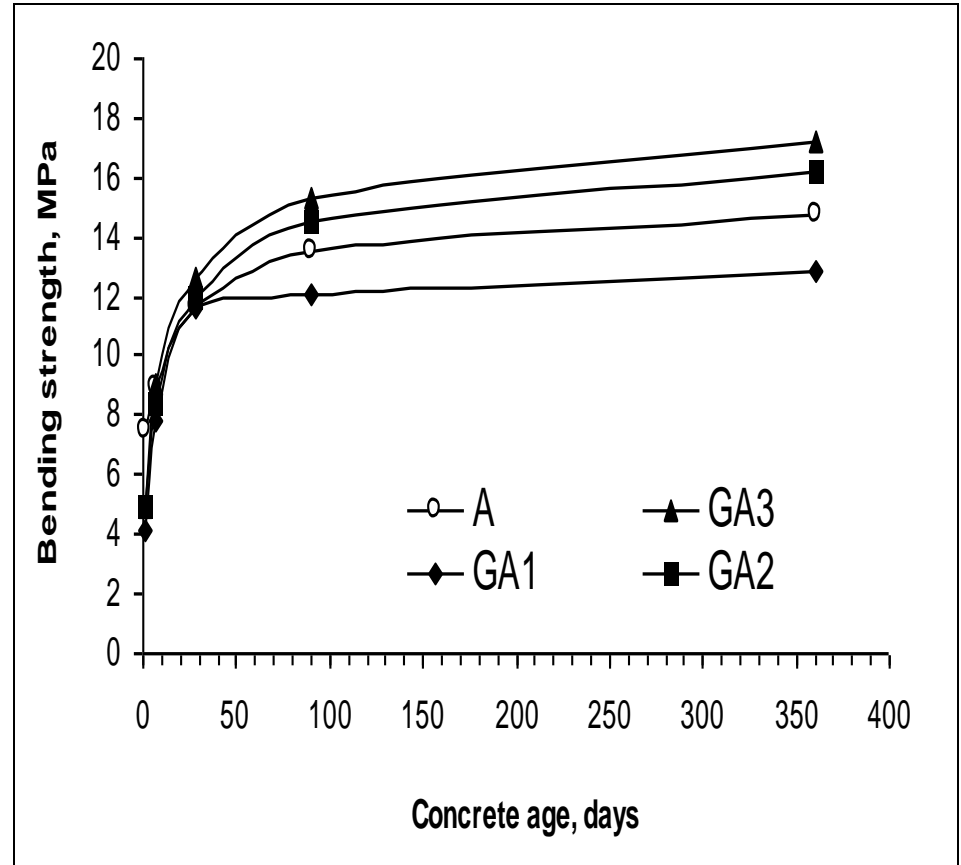
Bending strength of G concretes.



RESULTS AND DISCUSSIONS (4)

The bending strength of GA concretes:

- The best evolution of GA3 and GA2 concrete bending strength;
- E glass particles < 0.125 mm of GA3 and < 0.5 mm of GA2 concrete;
- High contribution to pozzolanic reaction and hardening structure development.



Bending strength of GA concretes

RESULTS AND DISCUSSIONS (4)

Comment: The bending strength evolution

- *The bending strength* of concrete with E glass showed a different evolution as compared to the compressive strength.
 - The bending strengths is the most sensible strength to microcracks development in concrete;
 - The hydrosilicates resulted in the pozzolana reaction stop development and can diminish the volume of the critical cracks in the binding matrix-aggregate transition zone,
 - This aspect can explain the greater bending strengths at later ages.
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CONCLUSIONS (1)

- The concretes with glass waste addition as pozzolana and fine aggregate were tested;
 - One of the main problem was been the control mode of the alkali-silica-reaction (ASR) associated to expansion and concrete damage.
 - The mortar bar method, with controlled temperature and R.U. conditions curing, emphasized that E glass waste cement mortar is characterized by the smallest expansion, of 0.24mm/m, lower than control value of 0.42 mm/m,.
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CONCLUSIONS (2)

- The best values of mechanical strength and dimensional stability were obtained for the concrete with 33% fine E glass particles substitute.
 - The reason of this phenomenon was been the pozzolanic character of the fine E glass particles.
 - The experimental results, could be a valuable reasoning for the E glass waste valorization, by its capacity to inhibit ASR associated expansion of concrete.
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Acknowledgements

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Thank you!



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