CARBONATION OF SOME CONCRETE MIXTURES USING RECYCLED CONCRETE AGGREGATES

Remus Chendes [1], **Corneliu Bob** [1], **Liana Iures**[1], **Sorin Dan**[1], **Catalin Badea**[1] , **Dan-Cristian Tănasie***[2]

[1] *Politehnica University Timisoara, Faculty of Construction, 2nd Traian Lalescu, 300223, Timisoara, Romania*
[2] *National Institute of Research & Development for Electrochemistry and Condensed Matter, 144th Dr. Aurel Paunescu Podeanu, 300569, Timisoara, Romania*
*e-mail: remus.chendes@upt.com , *tase@incemc.ro*

Abstract
Typical C16/20 concrete class has been studied in an accelerated carbonation experiments carried out under high CO2 concentration. The 100x100x100 mm cube specimens, prepared with natural aggregates and recycled aggregates, were stored for 28 days in water and have been tested (physical-mechanical characteristics). After 60 days of accelerated carbonation conditions test, in a protected environment - 50% carbon dioxide concentration, temperature 25 ° C and humidity 75-80%, the specimens were cleaved to determine the carbonation depth by phenolphthalein test on the faces in the splitting zone, measuring the minimum and maximum carbon dioxide penetration values. Correlation was made between the compressive strengths obtained for the studied specimens and the carbonation depth after the accelerated carbonation experiments in the protected environment.

Introduction
The construction industry plays an important role in the social and economic development. According to Eurostat, in July 2019, the construction sector in Romania registered an increase of 39.5%, being the first in the European Union. Only Hungary is approaching, with an increase of almost 33%, while in Bulgaria or Poland the increases are only a few percent and the average increase of the European Union is only 1.7%. [1]

But, the construction sector has a negative impact on the environment, by large CO_2 emissions (contributing to global warming), by large amount of construction and demolition processes wastes generated (uncontrolled disposal), also leading to the depletion of natural resources by over-exploiting them. The only ways to reduce this negative impact of this sector is reuse, recycling and waste reduction [2].

An option, for the concrete resulted from the demolition process is to be used as aggregates into a new concrete, instead of using as coarse aggregate and filler in road construction industry. [3].

By recycling the materials are changed into new products, preventing this way, the waste of potentially useful materials, reducing the consumption of fresh raw materials, the energy usage and the air and water pollution. [4].

Results and discussions
The study on the durability of recycled concrete was carried out in accelerated carbonation experiments, continuing the previous work on topic of RCA influence on carbonation depth, due to higher porosity (20-30%) of the concretes than those cast with natural aggregates in the mix. ([7],[8]).

The usual concrete class C16 / 20 cast with natural aggregate in the mixture, replaced by the recycled aggregate concrete (different granulometric fractions), obtained after an industrial building demolition has been studied into the experimental program (Table 1.) [8].

Table 1. Experimental mixture

Concrete Class	**Mixture**				**Water/cement ratio**
	CEM I 42,5R [kg/m^3]	**Mixture water** [kg/m^3]	**Admixture** [kg/m^3]	**Aggregate** [kg/m^3]	
C16/20	292	205	1,46	1694	0,7

The concrete mixtures belong to the class of consistency S3, the maximum size of the aggregate of 16 mm and a super-plasticizing additive was used.

It was proposed to replace 100% of the natural aggregate (NAT) with RCA (R1). The other mixtures R2, R3, R4 and R5 replace only certain granulometric fractions in the natural aggregate with the RCA, keeping the others granulometric fractions unchanged (Table 2).

Table 2. Granulometric fractions

	(100% NAT)	(100% RCA)	(NAT + RCA)			
	M1	**R1**	**R2**	**R3**	**R4**	**R5**
NAT:	0,0-16,0 mm	-	0,0-0,5 mm 1,0-16,0 mm	0,0-1,0 mm 2,0-16,0 mm	0,0-4,0 mm 8,0-16,0 mm	0,0- 8,0 mm
RCA:	-	0,0-16,0 mm	0,5-1,0 mm	1,0-2,0 mm	4,0-8,0 mm	8,0-16,0 mm

As the previous experimental work, the 100x100x100mm cube specimens were stored for 28 days in water, tested (physical-mechanical characteristics) and subjected to accelerated carbonation experiments (fig.1) in a protected environment - carbon dioxide concentration (50%), temperature (25 °C) and relative humidity (75-80%) (figure 3).

The three parameters - carbon dioxide concentration, relative humidity and temperature - were measured with the Testo 350XL analyzer (Fig. 2). [8]

Figure 1.Experimental setup

Figure 2. Testo 350XL analyzer

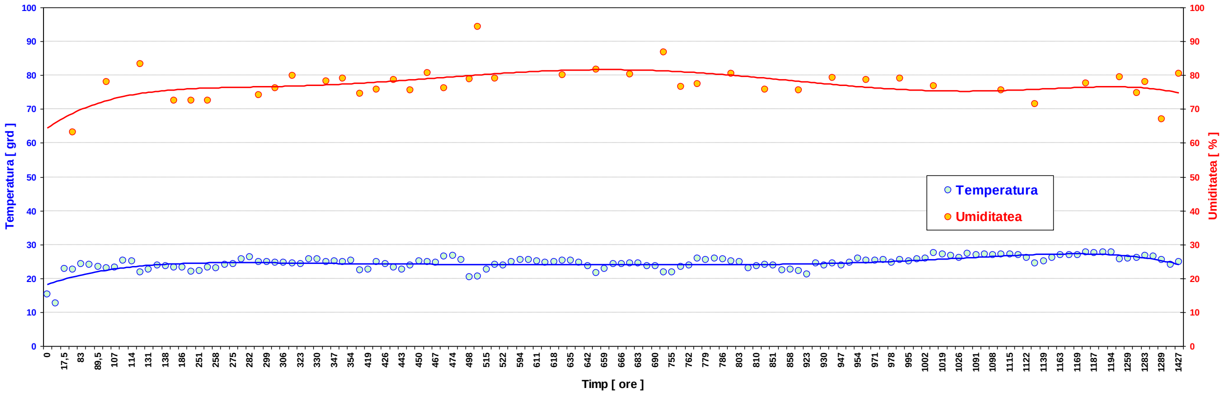

Figure 3.Temperature and relative humidity evolution

After being stored for 60 days under accelerated carbonation conditions, the specimens were cleaved to determine the carbonation depth after phenolphthalein test of the faces in the splitting zone, drawing the carbonated surface and measuring the minimum and maximum carbon dioxide penetration values (figure 4 and table 3).

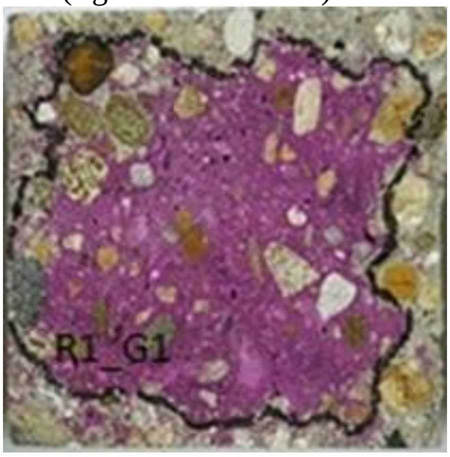

Figure 4. Phenolphthalein test - Carbonated surface [8]

In the calculation of the average depth of theoretical carbonation, the developed C.Bob formula presented below [6] was used:

$\bar{x}_{teoretic} = \frac{150 \cdot c \cdot k \cdot d}{f_c} \cdot \sqrt{t}$	$\bar{x}$ - average carbonation depth [mm] f_c - concrete compression strength [MPa] t - time [years] c,k,d - coeficients

Table 3. Experimental results

Samples	Compression strength f_c [Mpa]	c	k	d	Time [years]	x theoretic [mm]	x-min exp. [mm]	x-max exp. [mm]
M1 (100% natural)	29	1	0,7	2,7	0,164	3,96	4,0	11,0
R1 (100% RCA)	32,0	1	0,7	2,7	0,164	3,59	4,0	13,0
R2 (natural+RCA)	23,0	1	0,7	2,7	0,164	4,60	8,0	13,0
R3 (natural+RCA)	25,0	1	0,7	2,7	0,164	4,26	12,5	16,0
R4 (natural+RCA)	26,7	1	0,7	2,7	0,164	4,15	11,0	16,0
R5 (natural+RCA)	27,7	1	0,7	2,7	0,164	4,12	9,3	17,2

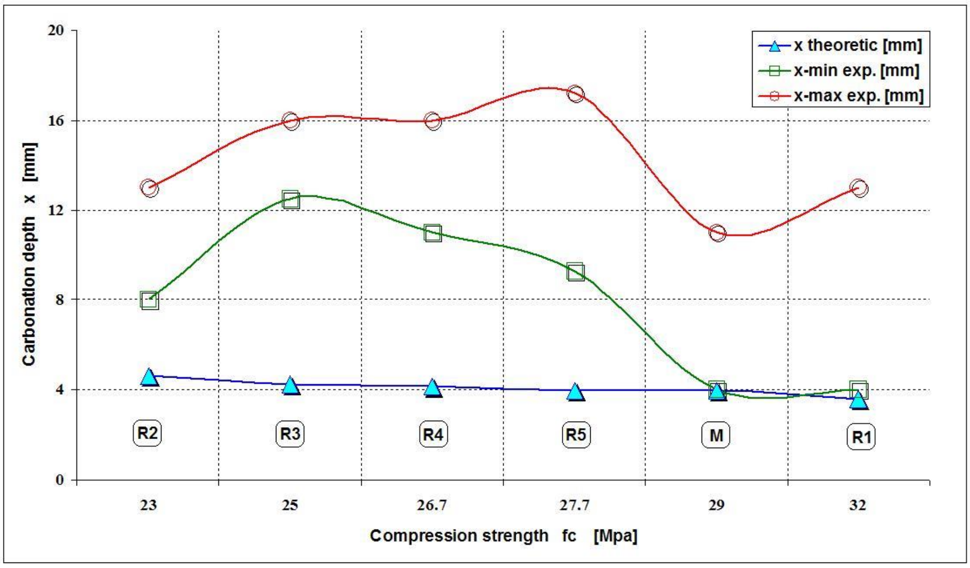

Figure 5. Carbonation depth vs. compression strength evolution

Conclusions

The additive added additionally in the case of studied mixtures, positively influences the carbonation depth.

As the grain size fraction replaced by RCA is larger, the compression strength is higher, but also the carbonation depth is greater.

Due to a quality control, difficult to manage, the results obtained for compression strength correlated with the carbonation depth, exhibit a different behavior from the results obtained in other studied cases.

References

[1] https://stirileprotv.ro/stiri/actualitate/constructiile-din-romania-cea-mai-mare-crestere-din-ue-ce-spun-economistii.html

[2] *Evaluations of existing waste recycling methods: A Hong Kong study.* Vivian W.Y. Tam, C.M. Tam. s.l. : Building and Environment, 2006, Vol. 41.

[3] C.Badea, *The Time Behaviour of Self Compacting Concrete With Fly Ash*, 17th International Multidisciplinary Scientific GeoConference SGEM 2017, Energy and Clean

Technologies, Issue 43, 27-29 November, pp. 259-265, Vienna, Austria, 2017
[4] M. F. Prada, S. Brata, D. F. Tudor, D. E. Popescu, *Energy Saving in Europe and in the World – a Desideratum at the Beginning of the Millenium Case Study for Existing Buildings in Romania,* Proceedings of the 11th WSEAS International Conference on Sustainability in Science Engineering, p.246 – 251, ISBN: 978-960-474-080-2, Timisoara, Romania, 2009.
[5] F.T. Olorusongo, *Early Age Properties of Recycled Aggregate Concrete*., Proceeding of the International Seminar on Exploiting Wastes in Concrete, University of Dundee, 1999.
[6] Bob, C., Verificarea calității siguranței și durabilității construcțiilor, s.l.Facla, 1989.
[7] Chendes R., Iures L., Popa R., Bob C., Dan S., Tănasie C. – Comparison between recycled concrete aggregates and natural aggregates density and water absorption, The national technical-scientific conference (international participation) „Modern technologies for the 3rd millennium" - the 17th edition, Oradea, Romania, 2018
[8] Chendes R., Iures L., Bob C., Dan S., Badea C., Tănasie C. - *Experimental determination of recycled aggregates concrete carbonation*, 24th International Symposium on Analytical and Environmental Problems, Szeged, Hungary, 2018