RESEARCH ON RECYCLING OF HARDENED MORTAR FROM CONSTRUCTION AND DEMOLITION WASTE

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ABSTRACT:

The recycling issues related to the construction and demolition (C&D) wastes in the sustainable development and the circular economy context represent a continuous challenge for researchers. This paper reveals the possibility to recycle the hardened mortar recovered from C&D wastes. Thus, the recovered hardened mortar with grains size less than 16 mm was used in the concrete structure. The compression resistance of the final concrete was determined using a Heckert 3000 KN testing machine and the results showed a better compressive strength for the samples with C&D waste content than the standard sample of about 1.19 times. This is a good premise for improving the researches related to C&D waste usage in concrete production.

1. INTRODUCTION

Annually, at European level, about 750 million tonnes of C&D wastes are generated, representing about 32.6% of the total wastes resulted from household and industry (Eurostat, 2015; European Commission, 2015).

Up to now, there are no public data regarding the C&D wastes in Romania. For example, in Italy the share of C&D wastes is: 30% concrete, 50% bricks, 5% asphalts, 6-10% excavation materials, 0.6-4% paper and cardboard, 3% metals and 1-1.4% others (Leopold et al., 2011). In Germany, the major C&D waste is made of 70% debris, 27% site waste and 3% waste from road repairs (Leopold et al., 2011).

The C&D waste, due to its large proportions, needs a special approach by the European regulations. In this way, the European policy requires that by 2020 the conditions for reusing and recycling of at least 70% (by weight) of the non-hazardous components of these wastes must be assured (Directive 2008/98/EC). With all these imposed measures, the C&D waste recycling share varies a lot from 10% to over 90% (European Commission, 2015). For example, in Germany, Denmark, Ireland, Holland and Great Britain the recycling share exceeded 70%, while in Spain, Poland, Greece, Romania and

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Bulgaria it was less than 20% (Eurostat, 2015; Jeffrey, 2011).

As it is already known, most of the recycled C&D waste represent excellent secondary raw materials for various industry branches and especially for construction industry (Bravo et al., 2015; Ledesma et al., 2014; Corbu et al., 2014; Rodriques et al., 2013; Wagih et al., 2013; Cojocaru et al., 2013).

The results of Martinez et al., (2013), reveal the possibility of successfully using the C&D waste as aggregates for masonry mortar manufacture. Moreover, as a result of physical and mechanical resistance tests it was found that the products that included recycled components had better characteristics than the standard samples.

2. METHODS AND MATERIALS

The tests and the physical and mechanical measurements of the concrete samples were made in the authorized Laboratory for material testing and analyses belonging to the CCIA branch of Baia Mare, within the Civil Engineering Faculty, Technical University of Cluj-Napoca. Other several tests can be made in this laboratory, such as: tensile tests, compression tests, bending tests for different types of material specimens.

To carry out the experiment using the hardened mortar as aggregate in concrete structure, the hardened mortar was sampled from a C&D waste mass resulted from demolition of some residential buildings. After pre-washing to remove impurities and organic wastes, the material was subjected to crushing and grinding operations using a mobile crusher of 1.5 KW. The resulted mortar was grinded until it was reduced to fractions less than 16 mm (figure 1).

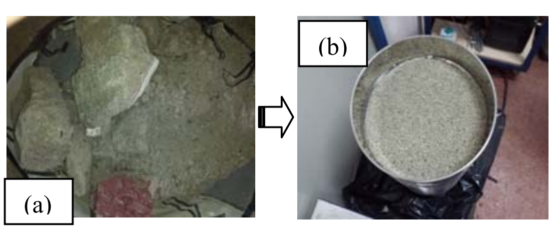

Figure 1. The hardened mortar before (a) and after grinding (b)

After the preliminary operation of preparing the mixture for concrete, the hardened mortar fraction, less than 16 mm, which replaces the sort of 0-4mm, was added to the concrete mixer content (of 0.4 m^3) in order to prepare the concrete. This would have a desired class of C16/20 (table 1-2).

The used recipe complies with the codes standards SR EN 206:2014, NE 012 –2009 and SR EN 12390-1,2,3: 2005 (table 1 and table 2).

Required project parameters	
Transport	*mixer, pumping*
Exposure class	*X0-no risc of corrosion or external attacks*
Period of execution	*Outside the cold period*
Element type	*reinforced concrete foundations, columns, beams, structural walls*
Cement grade	*42.5*
Aggregate	*0-16 mm*
Adittive1	*No*
Adittive 2	*No*
Humidity of the aggregate	*Un=0.0%, Up=0.0% (dry aggregates)*
Degree of permeability	*P4 (100mm water penetration at 4 atm pressure, on standard samples)*
Frost cleftness degree	*G100 (no. of cycles of frost/thaw the standard sample can take)*
Consistency	*S3-S3/S4-good for concrete pumps*

Table 1. Parameters for the concrete mixture

Charge volume = 1.00 (mc)		
The component	Dosage/mc	Dosage/ charge=0.02mc
Water	*190.00 liters*	*3.8 liters*
Cement	*265.00 kg*	*5.3 kg*
Pantarhit additive S (0.7% x C)	*0.00 kg*	*0.00 kg*
Additive 2	*0.00 kg*	*0.00 kg*
Sand 0-4 mm/ ground and sorted hardened mortar	*852.53 kg*	*17.05 kg*
Sand 4-8 mm	*378.90 kg*	*7.58 kg*
Gravel 8-16 mm	*663.08 kg*	*13.26 kg*

Table 2. The obtained concrete recipe

A cement grade of CEM II/A-LL 42.5 R from Holcim – Aleşd was used (SR EN 197-1:2011) in order to obtain the concrete.

After mixing, the material was poured into 3 cubic samples with the edge size of 15 cm to obtain the concrete class of C16/20 (SR EN 206:2014). Also, 3 standard cubes were prepared. The samples were filled with mortar (figure 2a) and were subjected to vibration on the shaking table until no air bubbles would come out (figure 2b).

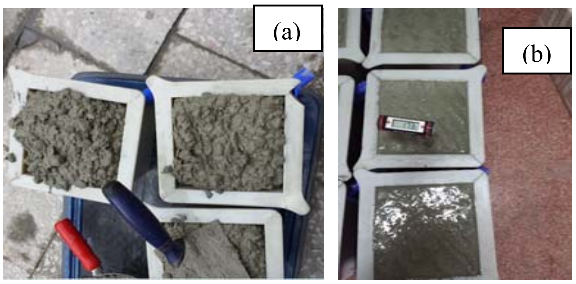

Figure 2. The specimens achieving: (a) filled samples before vibration; (b) filled samples after vibration

After 14 days, the concrete cubes were extracted from the samples and placed for hydration into a storage container with water for another 14 days, under controlled temperature of 20 °C (figure 3).

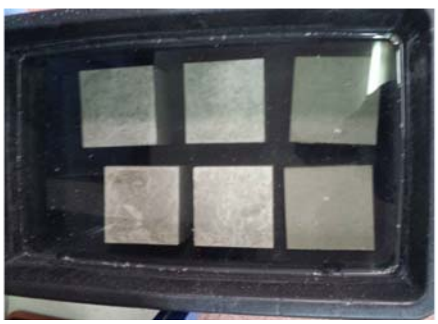

Figure 3. Hydration of concrete cubes

After removal from water, the concrete test cubes were held for 24 hours to dry and after that they were weighted. After 28 days they were subjected to compression tests to determine the physical-mechanical characteristics, namely the compression strength, using the Heckert 3000 KN testing machine (figure 4) (SR EN 206:2014).

The compression strength test was performed on test cubes of C16/20 class, in accordance with EN 12390-3, which provides a standard value of 20 N/mm^2.

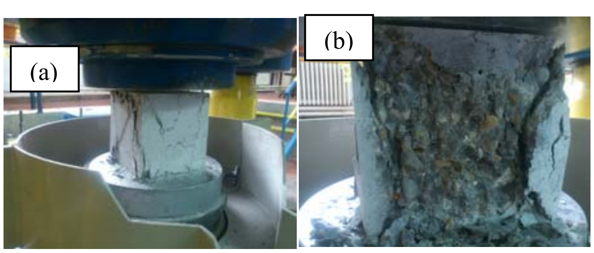

Figure 4. The concrete cubes during (a) and after compression (b)

The compression strength of concrete was calculated according to the formula:

$$R_C = \frac{F}{A} = \frac{F(N)}{150 \times 150\ [mm^2]} \quad (1)$$

where:

R_C – compression resistance [N/mm^2];
F – force;
A – cross sectional area of the specimen (compression area).

3. RESULTS AND DISSCUSION

After reading the results indicated by the analogic display of the testing machine, for concrete patterns (with recovered hardened mortar) a table with the notes and calculations was drawn up. These values are presented in tables 3-4. Tables 3 and 5 present the initial data that characterise each test, before the actual testing of the cubes (i.e. info sheets).

Indicative/No. Reg./Date	STUD 002	919	1	27/05/15
Reference norm:	*SR EN 12390-6:2002*			
Com. No.	–	–	- - -	29/04/2015
Sampling place/sampled by:	*Station*	*Customer*		
Position in the concrete schedule:	*1*			
Prepared at time/station/recipe	*29/04/15*	*Laboratory*	–	
Supplied in day/delivery note	*29/04/15*	–		
A. Properties of concrete				
Consistency class:	*?*			
Cement type:	*II A-LL 42.5R*			
Maximum aggregate size (mm):	*16*			
B. Test results				
Distinguishing sign and indicative:	*1 – samples (1,2,3)*			
Date of manufacture:	*29/04/15*			
Date of test:	*27/05/15*			

Table 3. Report on compressive tests on concrete cubes with waste aggregates

Characteristics pattern/Tests	I	II	III	Avg.
A (mm)	*150.00*	*150.00*	*150.00*	*150.00*
B (mm)	*150.00*	*150.00*	*150.00*	*150.00*
H (mm)	*150.00*	*150.00*	*150.00*	*150.00*
Compressive	*22500*	*22500*	*22500*	*22500*

area, (mm²)				
Cube weight, (kg)	*7.28*	*7.22*	*7.15*	*7.22*
Apparent density, (kg/m³)	*2157.04*	*2370.37*	*2118.52*	*2215.31*
Max. compressive force, (N)	*680000*	*660000*	*675000*	*671666*
$F_{ck,cube}$ (N/mm^2) after 14 days	*N/A*	*N/A*	*N/A*	*0.00*
$F_{ck,cube}$ (N/mm^2) after 28 days	*30.22*	*29.33*	*30.00*	*29.85*
Obtained concrete class				20/25
Proposed concrete class				16/20

Table 4. Characteristics of the tested concrete cubes containing waste aggregates

To compare the obtained results between the concrete cubes using recycled C&D waste and the standard cubes (C16/20), both series were subjected to compression tests. The results are presented in tables 5-6. The calculations and the results are based on the data provided by the test reports issued by the Laboratory for material testing and analyses belonging to the CCIA branch of Baia Mare, within the Civil Engineering Faculty, Technical University of Cluj-Napoca (tables 5-6).

Indicative/No. Reg./Date	Stud 001	919	0	27/05/15
Reference norm:	*SR EN 12390-6:2002*			
Com. No.	—	—	---	29/04/2015
Sampling place/sampled by:	*Station*	*customer*		
Position in the concrete schedule:	*1*			
Prepared at time/station/recipe	*29/04/15*	*Laboratory*	—	
Supplied in day/delivery note	*29/04/15*	—		
A. Properties of concrete				
Cement type:	*II A-LL 42.5R*			
Maximum aggregate size (mm):	*16*			
B. Test results				
Distinguishing sign and indicative:	*0 – Pattern (1,2,3)*			
Date of	*29/04/1*			
Date of test:	*27/05/15*			

Table 5. Characteristics of standard concrete cubes

Characteristics pattern/ Tests	I	II	III	Avg.
A (mm)	*150.00*	*150.00*	*150.00*	*150.00*
B (mm)	*150.00*	*150.00*	*150.00*	*150.00*
H (mm)	*150.00*	*150.00*	*150.00*	*150.00*
Compressive area, (mm²)	*22500*	*22500*	*22500*	*22500*
Cub weight, (kg)	*7.72*	*7.60*	*7.65*	*7.66*
Apparent density, (kg/m³)	*2287.41*	*2370.37*	*2266.67*	*2308.15*
Max. compressive force, (N)	*645000*	*655000*	*645000*	*648333*
Fckcub (N/mm^2) after 14 days	—	—	—	*0.00*
Fckcub (N/mm^2) after 28 days	*28.67*	*29.11*	*28.67*	*28.81*
Obtained concrete class				20/25
Proposed concrete class				16/20

Table 6. Characteristics of standard cubes, after test

Due to the presence of the recovered mortar which also contains cement, the resistance of the specimens with recycled aggregates is slightly increased than the standard cubes. The specimens had a smaller weight, as results from the data presented in tables 4-6.

It is to be noted that the compressive strength of concrete specimens containing aggregates from recycled materials was higher than that of the standard specimens. Comparing the characteristic values of concrete compressive strength, determined by testing cubic specimens after 28 days, values of 29.85 (N/mm^2) for concrete containing waste, and of 28.81 (N/mm^2) for standard specimens, were obtained.

Compared to the value of 20N/mm^2 provided by SR EN 206: 2014 for concrete C16/20, the concrete obtained with the addition of recycled materials has a compressive strength of 1.19 times higher than the standard one. This indicates that, by using waste materials as an aggregate in concrete composition, one can easily obtain quality products. This supports the tendency of European policies to increase the percentage of recycling construction and demolition waste and whenever possible, turning waste into secondary raw materials according to the concept of "circular economy" (European Commission, 2015; Meyer, 2011).

4. CONCLUSIONS

In the overall context of sustainable development and based on the concept of "circular economy" the recycling of construction and demolition waste attracts an increased attention by finding technical solutions to meet the mentioned objectives. Reports of international scientific research reveal that this waste has found various uses, often being used as aggregate for achieving products in the construction industry.

The achieved concrete including aggregates from C&D waste recorded a good quality, comparable with a standard one. These remarks are sustained by the test results presented in the test reports for the two sets of concrete cubes (standard and with waste aggregates).

In the context of knowing the chemical composition of the recovered C&D waste, the cement dosage provided by the standard recipe may be reduced, but only after preliminary tests. The results presented in this paper could encourage the use of recycled C&D waste as aggregate in concrete and may provide a benchmark for further research regarding the possibility of recovery and usage of the C&D waste. These may be used as secondary raw materials for achieving new products especially - for the construction industry.

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