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THE INFLUENCE TO THE IMPACT STRENGTH OF THE RECYCLED RUBBER GRANULES ADDITION ON THE CONCRETE STRUCTURAL ELEMENTS

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Abstract: *Concrete buildings elements having modified mixes improved physic properties and mechanical characteristics (strength) of the material. However, the role of the rubber recycled granules addition should not be reduced only to this principle (strengths improvement), but also, to control the cracking's process evolution and, thereby, to energy absorption properties and impact resistance, shock, temperature variations, to fire resistance.*
The present paper offered to specialists, a new approach to achieve a concrete mixes with the recycled rubber granules from waste tires, that could solve two major problems in this field: improving impact/shock resistance of concrete's structural elements, as well as to the environmental pollution refinement (by non-biodegradable items) through its integration into construction materials.

Key words: recycled rubber, impact strength, concrete with recycled rubber.

1. Introduction

The choice of concrete for a certain engineering work, must be made taking into account its properties, such as permeability, resistance to repeated freeze-thaw cycles, corrosion resistance in aggressive chemical environments, etc; but remain determining in every case the mechanical strengths and deformation properties of concrete.

Global reuse of waste through their integration in the field of construction materials has become an issue of most importance that can help prevent environmental pollution and at the same time contributing to the development of buildings with lower-cost and, why not, improve performance of the materials used.

Accordingly, the use of rubber aggregates in concrete has become more important and has become a topic of research since 20 years ago.

Used tyres can be used in two manners: material (recycling) and thermal (through co-incineration in cement factories). As a result of recovery materials, used tyres are turned into rubber powder of different sizes (pellets), steel and synthetic yarn.

This article proposes two targets:

- the evaluation by comparison (static tests) at the impact resistance of concrete with addition of recycled rubber granules;

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- the influence of the rubber granules addition on the compression of prismatic concrete specimens.

2. Experimental procedure

For carrying out the test of impact resistance to the concrete there was made 16 specimens having each side of the cube-shaped 150 mm (according to SR EN 12390-1:2013). 4 specimens for each mix (without the addition of rubber, 5%, 10% and 15% of the fine aggregate 0-4 mm replaced with rubber granules). The samples were kept in room air-conditioners for 28 days, within seven days they were submerged in water, after which they were tested.

Fig. 1. *Cubic specimens in climatic room*

Have been achieved a total of 16 cubes, 4 for each kind of mix:

-concrete C16/20 (no);

-concrete having replaced the content of sand percentage of 5%;

-concrete having replaced the content of sand in a percentage of 10%;

-concrete having replaced the content of sand in a percentage of 15%.

Rubber quantity and the other materials quantity for concrete mixes are presented in Table 1.

Materials quantities for every concrete's mixes Table 1

Rubber quantity [%]	Material (kg/m^3)				
	Water (l)	Cement	Sand	Gravel	Rubber
0%	190	355	945	987	0
5%	190	355	897.75	987	47.25
10%	190	355	850.5	987	94.5
15%	190	355	803.25	987	141.75

In the experiments, each sample was subjected to dynamic shocks with Föppl hammer, to measure the hammer's recoil. Whereas at the same time are known and the values of the height from which it is fall the hammer, measured its weight and dimensions of cubes sides, it can be calculated the total energy induced in the sample, and the energy absorbed by the pieces as a difference between the potential energy of the Föppl hammer in the release moment and the potential energy of his after hitting the sample and subsequently to reach maximum height due to the recession.

By hitting the sample undergoes a total global deformation response of elastic element deformation plus plastic element deformation. Plastic component of the strains is more emphasis for the plain concrete (with natural stone aggregates) and through experimental results validating the theoretical conclusions which stated that the link's destruction from inside and outside the matrix leads to a certain ductility of concrete, allowing it to dissipate significant quantities of energy before fracture. This property has a great importance especially if concrete elements are subjected to dynamic actions.

It also wants to be checked of an eventual increase in the ductility and the growth potential to shocks-proof and be impact-resistant concrete that contains a certain percentage of aggregated results from tyre recycling of used tires.

2.1. Instrument used

Föppl Hammer (Fig. 1) is generally used to determine the shock resistance of the natural and artificial stone aggregates. This instrument could be adapted also to test the cubic concrete specimens, in order to determine the impact resistance (Fig. 2).

2.1.1. Instrument's description

Föppl hammer is composed by an anvil (1), two columns (2) in which slid port-hammer (3) and the proper hammer (4).

From the column on the right there is a ruler with graduated sizes from 5 mm (5) to measure the height of fall.

The left column is fitted to a ruler (6), millimetre in size, used for measuring the recoil (rebound).

Lifting points up at the height of drop is done using manual winch (7) and through the hook (8) at the port-hammer, and triggering the fall of the hammer is done with the help of the handle (17).

Piling on is found two cursors fitted stoppers (9) which together with the claws (10) and levers (11) are designed to block the hammer, after recoil, into a particular position.

On the hammer is fitted to the lever (12), the recoil will move the cursor ruler (6).

Test specimens from natural or artificial stone sits in the plate for testing (13) over who is sited the superior plate (14).

2.1.2. Technical characteristics

Föppl hammer has the following technical characteristics:

a) hammer's weight G = 50 ± 0,5 kg
b) hammer hardness R_B = 200
c) hammer fall max height H = 1500 mm
e) anvil's weight G = 500 kg
f) anvil's hardness R_N = 200
g) instrument's total weight G=800 kg
h) max dimensions 1080×450×2860 mm

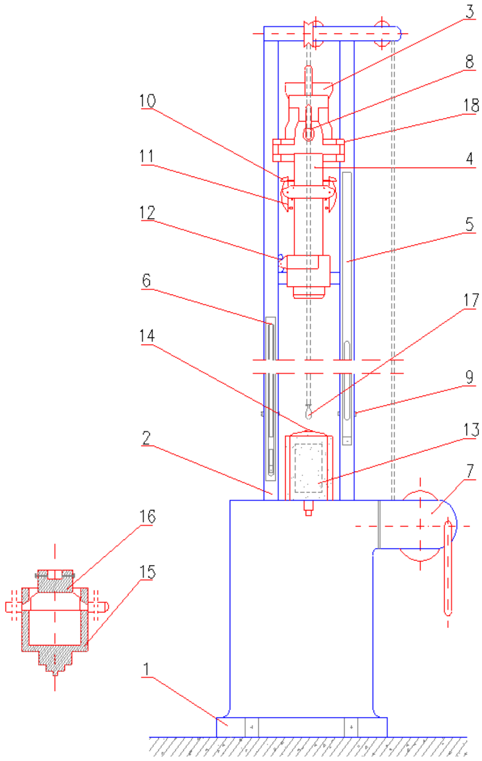


Fig. 2. *Föppl Hammer*

2.2. Determination procedure

Determination of impact resistance of the concrete cubic test specimens is performed by following these steps:

a. lay down the port-hammer (3) using the hand winch (7) and using the hook (8) at the port-hammer, the hammer (4) is attached .

b. raise the hammer to a certain height so that the specimen can be placed in the middle of the testing plate (13).

c. sits on top of the specimen the upper plate (14).

d. allow the hammer to support over the upper plate.

e. the claws (10) snaps into locked position using the lever (11).

f. cursors stoppers (9) are fixed at a

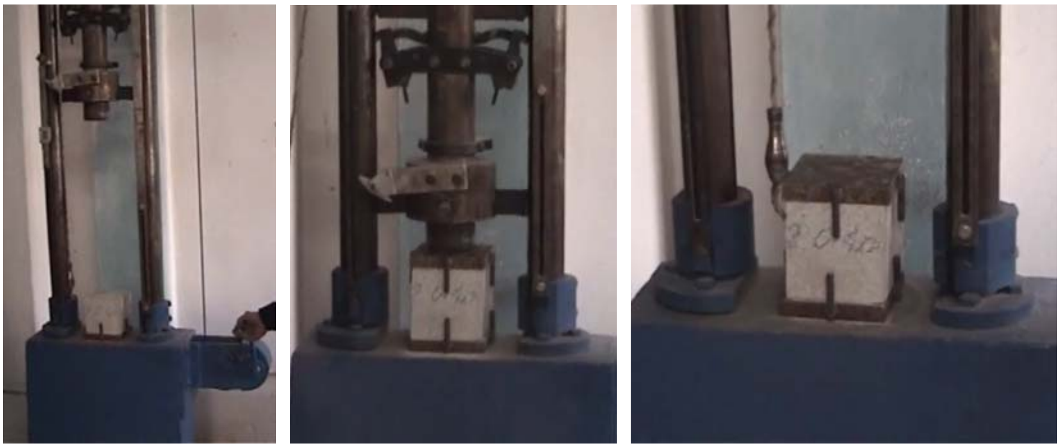


Fig. 3. *Cubic specimen's placing in order to determine the impact test*

certain height, so that the fall of hammer, the recoil, it does not rely on the superior plate.

g. graduated Ruler (5) sits so that the indicator (18) to be placed in the right part zero.

h. the graduated ruler (6) so that the levers (12) (which must be based on slider ruler) to find the zero position.

i. rises up the hammer to the height indicated in the STAS 730-49, regarding to the determination of shock resistance.

j. to order the hammer's release, by releasing the hook (8) helping by the handle (17).

k. read on the graduated ruler (6) the height of the hammer's recoil.

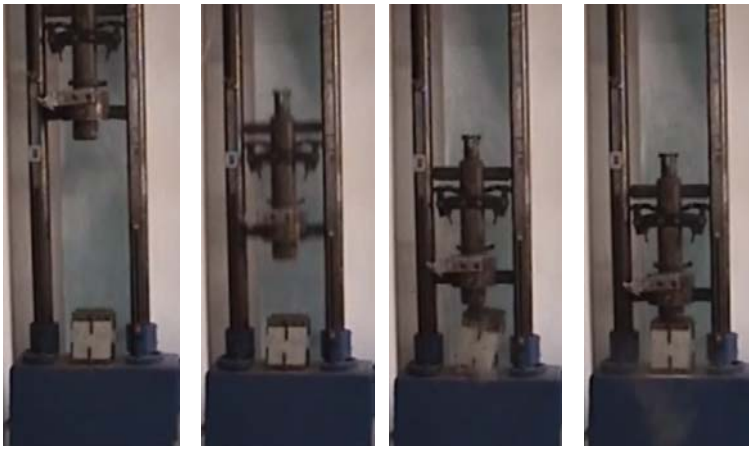
2.3. Results and its interpretation (impact test)

As a result of tests carried out in accordance with the procedure described in item 2.2, the following were noted:

- The impact of hammer with control specimens (no rubber) were produced without a rebound significantly (approx. 1-2 mm), having local minor damage of the tested specimens (fig. 4 c);

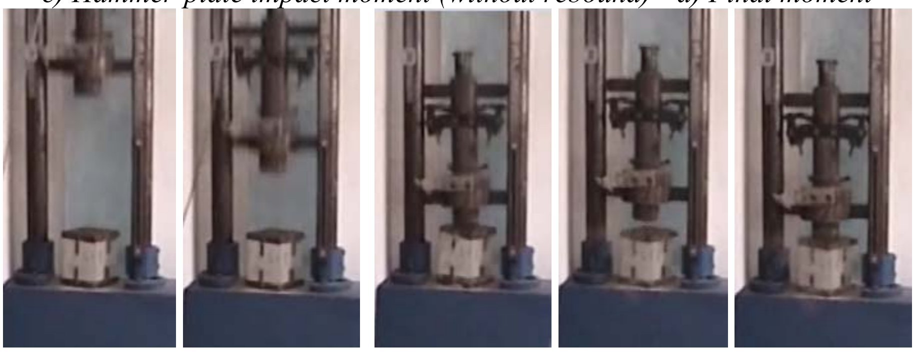
- The results of the impact of the hammer with specimens with granular rubber have different recoil, strictly in accordance with the amount of aggregate replaced. Thus, for the specimens with the addition of rubber at the rate of 5% (Fig. 5 d) is found a rebound of approx. 4 cm and for those with the addition of rubber in the proportion of 15% (Fig. 6 d) shows a rebound of approx. 6-7 cm. The impact occurred without major implications on the status of test specimens, so without producing damage fracture occurs at the contact with the upper plate.

- So increasing the amount of rubber granules replaced in the concrete's mixes brings an increase of elasticity and ductility of concrete specimens, but (as is indicated graphically in Fig. 9) with negative input resistance to compressive strengths.



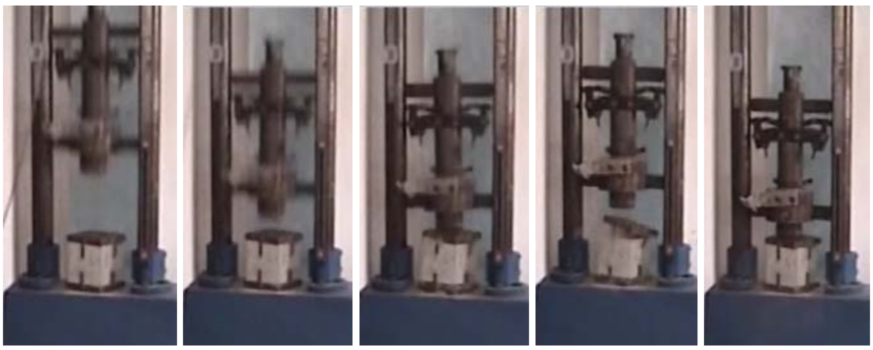
a) b) c) d)

Fig. 4. *Test of the control specimen (without rubber granules)*
a) Initial moment b) Hammer falling moment
c) Hammer-plate impact moment (without rebound) d) Final moment



a) b) c) d) e)

Fig. 5. *Test of the mix 1 specimen (with 5% rubber granules)*
a) Initial moment b) Hammer falling moment
c) Hammer-plate impact moment d) Rebound moment e) Final moment



a) b) c) d) e)

Fig. 6. *Test of the mix 3 specimen (with 15% rubber granules)*
a) Initial moment b) Hammer falling moment
c) Hammer-plate impact moment d) Rebound moment e) Final moment

3. Determination test of the compressive strength

Cube-shaped test specimens were tested in compression with Universal Testing Machine 300tf from the Faculty of Civil Engineering and Building Services of Iasi, according to SR EN 12390-4: 2013.

Have been prepared in accordance with the conditions contained in the SR and tested 4 pieces for each concrete's mixes designed.

Fig. 7. *Determination test for compressive strength with 300tf UTM (300tf Universal Testing Machine)*

0% 5% 10% 15%

Fig. 8. *Collapsed specimens after test (different percent rubber granules)*

The addition of recycled rubber granules in concrete's mixes changed mechanical properties of specimens. The main disadvantage of the use of recycled rubber granules is that it reduces mechanical resistances. The addition of 15% of rubber granules into concrete results in a decrease in compressive strength with 48% (Table 2).

Compressive strength Table 2

Specimen type (rubber percentage)	Weight [kg]	Compression [MPa]
Control (0%)	6.648	36.93
Mix 1 (5%)	6.446	25.91
Mix 2 (10%)	6.175	22.70
Mix 3 (15%)	5.729	19.18

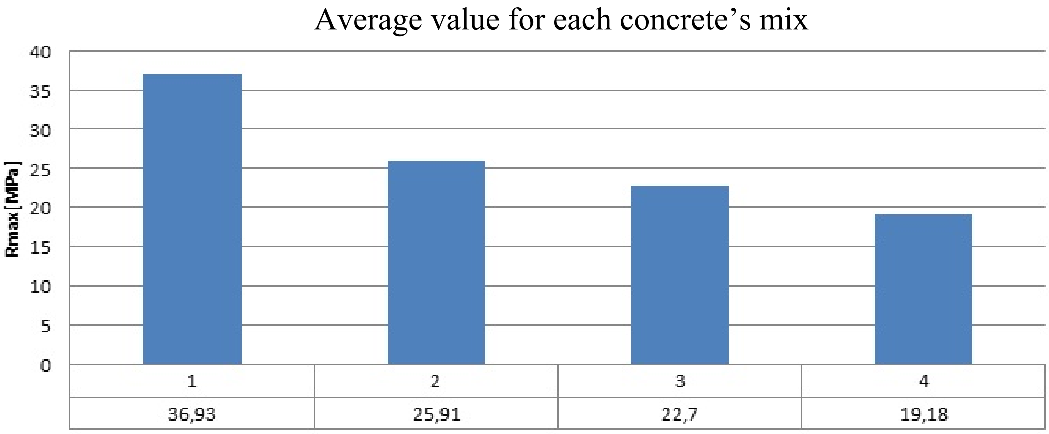


Fig. 9. *Compressive strength variation for the concrete cubic specimens having different rubber quantity*

4. Final remarks

The experimental programme which is the subject of this article, aside of the field of research are less studied, taking into account the limited number of publications regarding the embedding recycled rubber waste in concrete composition.

Current research has shown that there are two areas where we can appreciate that the concrete with admixture of rubber aggregate versus normal concrete mixtures, can offer advantages in fine condition:

Firstly, where rubber aggregates decreases the specific weight of the mixture with a higher intake of air which makes pumping to be easier, and provides better thermal insulation and/or acoustic.

Secondly, rubberized concrete provides a large increase in impact absorption characteristics and vibration.

Concluding, it requires a clear definition of the concrete made with aggregates in rubber and enter it in the current standards and procedures.

Thus, one can opine that the use of coarse granular rubber (large aggregates) or rubber powder should be minimized or avoided in favour of granulated rubber that has reduced the cost implications and the resistance. According to the results recorded in the numerical experimental it is observed that with the growth potential of picking up shocks (Figure 4, 5, 6) shows a decrease of compressive strength (expressed in Table 2 and graph from Figure 9).

So, the replacement rate of the aggregate shall not exceed 15 per cent of its volume, in order to maintain an acceptable level of strength and rigidity for the rubberized concrete is suitable.

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