Influence of the Circular Reinforcement on the Young's Modulus of Elasticity

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Abstract: The article is focused on the comparison of material characteristics - modulus of elasticity for two different materials. The first material is plain concrete, the second is concrete clamped in metal rings with different thickness and distribution of clamping. The rings into which the cylindrical body is concreted are made of aluminum alloy EN AW 6060 T66. The strength of concrete has a decreasing trend with decreasing number of encircling rings, as well as decreasing ring thickness.

Keywords: Young's modulus of elasticity; concrete; circular reinforcement; compression test; strain measurement.

1 Introduction

Efforts to minimize the energy intensity of the construction industry lead not only to changes in the material properties of building materials, but also to the optimization of load-bearing structures. With the correct design of the supporting structure, it is possible to realize a slimmer, and thus less energy-intensive structure. Concrete is one of the most energy-intensive building materials. Efforts to slim concrete structures lead to the use of the maximum capacity of material properties of concrete. One possibility is to use annular reinforcement to catch the transverse bars in the pressed structures [1]. The external reinforcement of the concrete structure will affect the material properties of the concrete. Attention in this article is paid to mechanical properties. Such properties include compressive strength and Young's modulus, in particular [2].

Prepapation of mixture was realized by cement CEM I 42.5 R [3] as is possible see in Tab. 1.The amount of mixing components in the table is based on 70 kg of mixture. This amount was sufficient for the preparation of bodies within two days, ie. for 18 samples. The next day after concreting, the specimens were demolded and stored in water boxes, but were not immersed in water. Concreting was realized during two days. One day before testing, the surface of the upper pressure surface was treated by grinding. The testing took place at the age of 27 and 28 days, respectively. The homogeneity of the manufactured bodies was checked by determining the bulk density for a set of bodies tested in 1 to 4 days. The volume weight variance was 100 kg/m^3 for sets 1 to 4 as is possible see in Fig 7.

Tab. 1: Mixture of concrete.

Parts	kg
Cement	11.480
Water	4.760
Sand	22.310
Aggregate 4–8	12.600
Aggregate 8–16	14.800
Superplasticizer Stachement F	0.114

Tab. 2: Measured material properties of sets.

Rings/thickness	12/3	8/3	12/2	8/2
Volume weight [kg/m^3]	2581	2509	2471	2466
Compressiion strength [MPa]	77.31	67.35	70.03	63.88
Modulus of Elasticity [GPa]	35.79	35.18	38.47	36.42

2 Preparation of tests

The comparison was performed on concrete cylinders 200 mm high and 100 mm in diameter. The production and concreting of the specimens was carried out in two steps. Firstly was concreted specimens with 3 mm thicknes of rings, and secondly with rhickness of aluminum rings 2 mm. Both mixtures were accompanied by the production of specimens without rings on the surface. This compared the preservation of the same properties of both mixtures. 18 bodies with rings th. 3 mm was made on the first day and 18 bodies with rings thickness 2 mm was made on the third day. Of the 18 bodies, 9 bodies were designated for testing the first set and 9 bodies for testing the second set. The first set contained 4 ordinary cylinders and 5 cylinders with 12 rings. The second set contained 4 cylinders without rings and 5 cylinders with 8 rings. Each set was tested for one day.

The test of each sample was controlled by increasing the force to a load level of 200 kN. Further loading proceeded under the control of the deformation increment. The experiments were carried out until the specimens were completely broken.

3 Description of instrumentation of tested specimens

The specimen testing procedure was performed in accordance with the requirements of the standard for testing concrete in compression [4]. Each specimen was fitted with two extensometers 100 mm long to measure axial deformation. Some specimens with rings were equipped with strain gauges for measuring horizontal deformations on aluminum rings, see Fig. 1 in the region of half the height of the body. The working diagrams were measured up to the failure of the bodies. Breakage of the aluminum rings was noted in the working diagrams, as well. This is very clearly viewable in Fig. 2.

Fig. 1: The cylinder specimen after compression test. The specime was tightened with 12 rings thickness 2 mm.

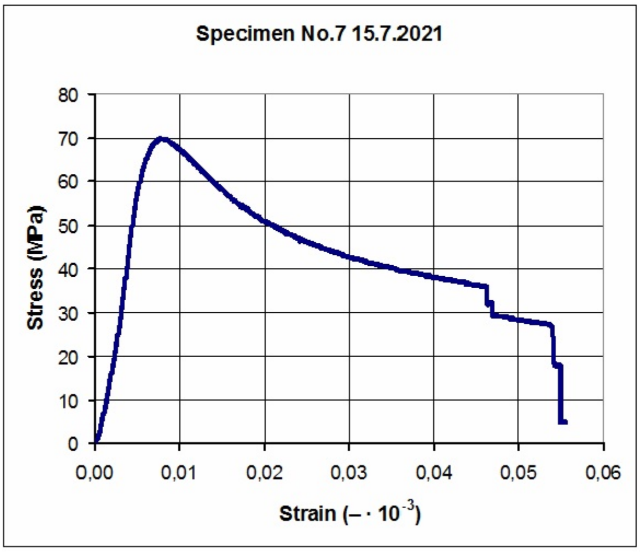

Fig. 2: Stress-strain graph of specimen with 12 rings, thickness 2 mm.

The specimens with rings were sprayed with paint to measure deformations using digital image correlation, as can also be seen in Fig 1. But our focus is on comparing compressive strength as well as modulus of elasticity on bodies with different numbers of rings and different ring thicknesses.

4 Comparison of measured parameters

The compared parameters were the average compressive strength of the specimens and the average value of the modulus of elasticity. The strength was determined as the ratio of the highest achieved force and the loaded area. The modulus of elasticity was determined as the shear value between the initial state and the value of stress and relative strain in 1/3 of the compressive strength of the specimen. The correct method of cracking the concrete cylinders in the compression test was checked so that it corresponded to the correct shape of the test specimens defined by the concrete pressure test [5].

The average compressive strength of ordinary cylinders was 45 MPa and the Young's modulus was 37 GPa. These values were achieved for both sets. The selection of test specimens for the test in one day was random from the number of specimens made from one mix. Therefore, it can be stated that even for the third and fourth tested sets, the average value of compressive strength corresponds to the strength of the first and second tested sets. The properties of the first and second mixtures are equivalent, see Fig 3. Fig. 3 and 5 show the achieved values of compressive strength and Modulus of elasticity of specimens without circular reinforcement.

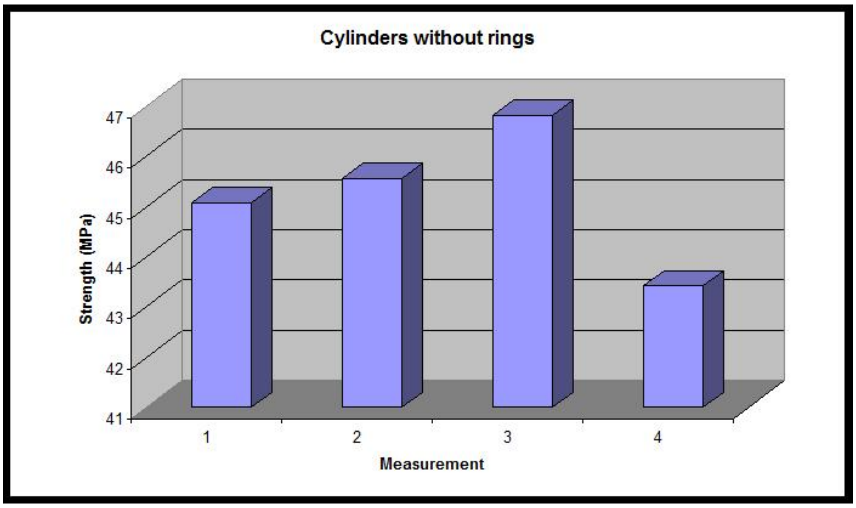

Fig. 3: Compression strength of cylinders without rings .

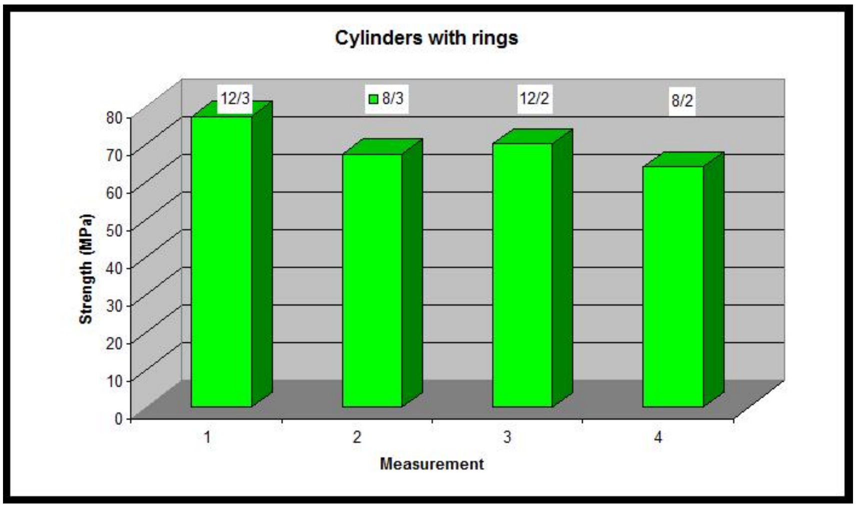

Fig. 4: Compression strength of cylinders with rings .

In contrast, Fig. 4 and 6 show the compressive strengths and the modulus of elasticity of the rings reinforced specimens. The number of rings and the thickness are indicated in the graphs by a fraction in which the first value means the number of rings and the second value is the thickness of the rings. Sets 1 to 4 correspond to Figs. 4 and 6.

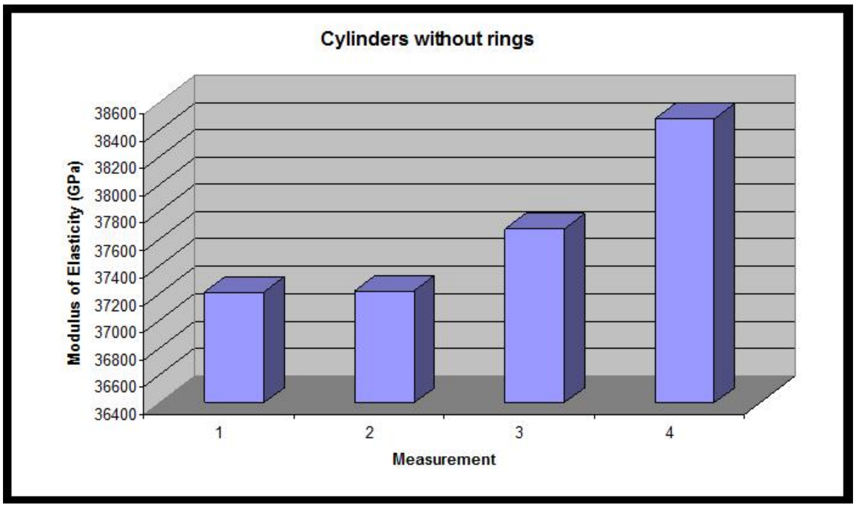

Fig. 5: Modulus of elasticity measured on specimens without rings.

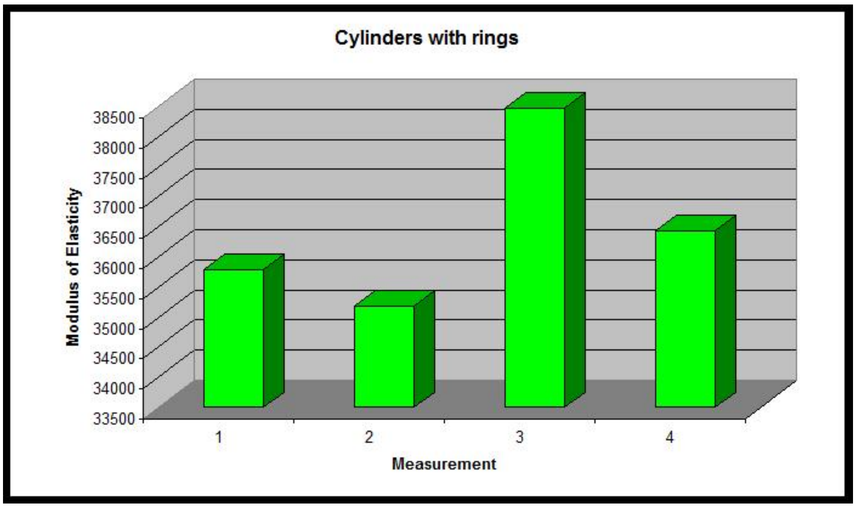

Fig. 6: Modulus of elasticity measured on cylinders with rings.

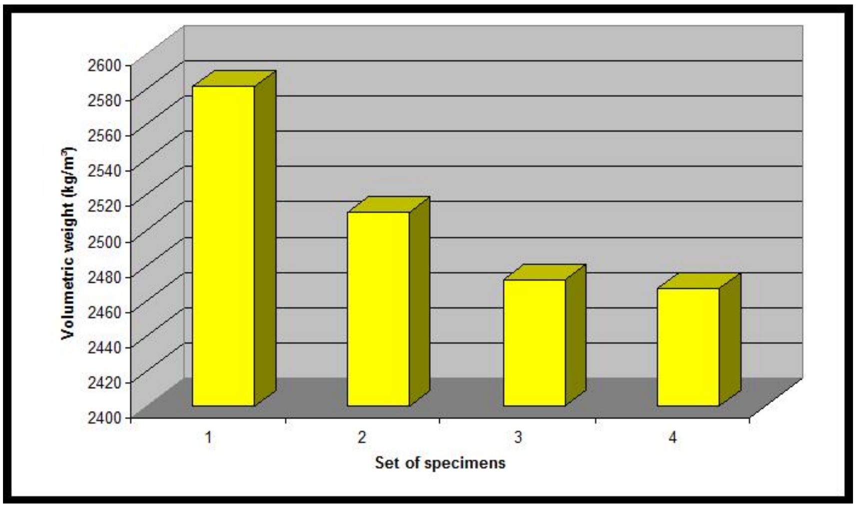

Fig. 7: Volumetric weight sets of speciems used for testing frrm 1^{st} to 4^{th} day.

5 Conclusion

The compressive strength has a decreasing trend, which depends on the thickness of the rings on the bodies, as well as on their number, as is possible see in Tab. 2. This table also shows that the volume density was affected by the amount and thickness of the aluminum rings. The number of rings affected the value of compressive strength. A higher number of rings increased the strength of the concrete. Compared to the basic value of compressive strength, the strength of bodies with 12 rings and 3 mm thick was 72 % higher.

The modulus of elasticity shows the opposite trend. The presence of aluminum rings on the specimens reduced the modulus of elasticity. The lowest value of Youn's modulus of elasticity was reached by specimens with 12 rings 3 mm thick. The reduction in the value of the modulus of elasticity is up to 4 %. Significantly ductile behavior of the strength part of the working diagram can be seen in Fig 2.

As can be seen in the working diagram on Fig. 2, the shape of the descending branch depends on achieving the bearing capacity of the enclosed reinforcement. By supplementing the concrete elements with reinforcement by means of external fastening, there is a significant potential in the use of strength properties, or in the possibility of reducing the amount of concrete in the structure. The failure shape of concrete bodies corresponds to the failure of specimens with circular reinforcement [6].

Acknowledgement

This research has been supported by project Grant Agency of Czech Republic GACR No.19-253125 "Compression tests with confinement for advanced modeling of concrete columns".

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