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Baj A., Lapko A.

THE INFLUENCE OF FREEZING AND THAWING CYCLES ON THE DEFORMATIONAL CHARACTERISTICS OF RC BEAMS

Concrete resistance to cyclic freezing and thawing is typically controlled on the samples in an unloading state. Very few experimental tests have been only conducted on the concrete samples subjected to combined static load and frost effects. In the paper the authors describe an innovative testing procedure for RC model beams made of RAC under constant bending moment and cyclic freezing and thawing. The aim of such studies was to clarify the effects of interaction of climatic and mechanical load on the deformability and cracking state of RC beams made of recycling aggregate concrete. The beams located in the climatic chamber have achieved over doubled deflection values in comparison with analogical beams loaded in room temperature. The results of current, as well as further planned research will let us develop the guidelines for using recyclable materials in concrete structural elements. Both adopted technical solutions and research procedure, as entirely innovative designs, were enclosed in submission to the patent register.

1. Introduction

In relation to the development of the construction and a lot of the building waste (for example from demolitions or rebuilding existing structures) a need of their recycling appears what is also required by the EU [2]. Applying of recycled aggregate concrete (RAC) is one of solutions to this problem.The previous investigations [1,3,7,9,10] showed differences in the behavior of structural elements made of RAC compared to members totally made of natural aggregate. The beams made of RAC cracked earlier and showed greater deflections at comparable loads, as well as grater shrinkage strain and creep characteristics. Moreover the compressive and tensile strength of RAC, the durability of such concrete is a very important aspect, influenced by freezing/thawing effect [11]. The examination of the RAC carried out up to now was conducted on the unloaded samples. Very few experimental tests have been only conducted on the concrete samples subjected to combined static load and frost effects.

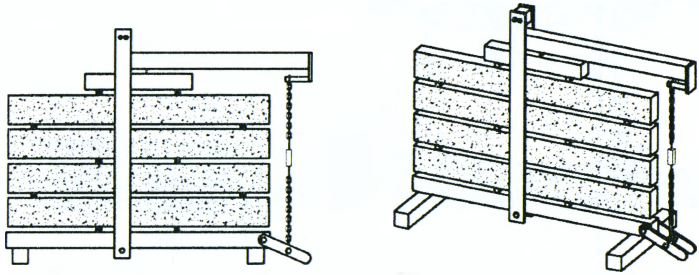

Figure 1 – Method of testing of concrete prisms under freeze-thaw cycles and sustained load [4]

In the fig. 1 are presented methods of testing of concrete prisms which were exposed to freeze/thaw cycles [4]. Essence of this research was determine the influence of combination different kind of loads: climatic, static and physical-chemical effects.

The deep review of current scientific publications on deformability (deflections, strains and crack widths) in RC beams made of recycling aggregate concrete (RAC)

shows that there is the lack of tests results for members under combined sustained static load and on freezing and thawing cycles.

The aim of experiments conducted by the research team of Bialystok University of Technology was to clarify the effects of interaction of climatic and mechanical load on the deformability and cracking state of RC beams made of recycling aggregate concrete [6].

2. Conducted research

The experimental investigation on RC model beams has been conducted with the use of following types of model RC beams:

- SR - RC beams entirely made of recycled aggregate concrete,
- SN - reference RC beams entirely made of natural aggregate concrete.

For the research on the influence of freezing/thawing cycles on the RC beams deflections an innovative stand shown in the Fig. 2 has been designed. The three-point loading scheme was assumed. The tested free standing model beams were turned back during the long term tests so that the tensioned zone was located in the upper part of model beam.

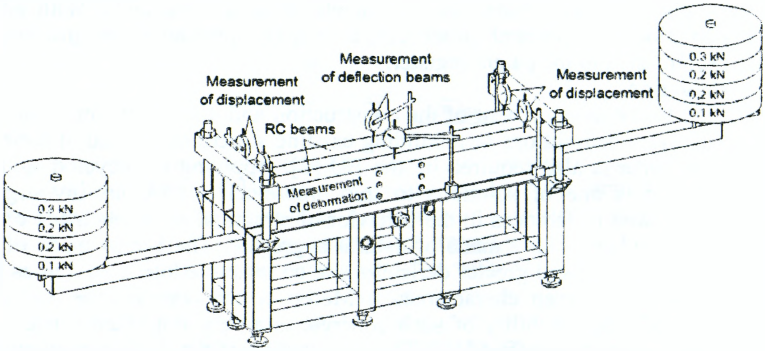

Figure 2 – The scheme of research stand with two tested model beams under static load and freezing and thawing cycles [5]

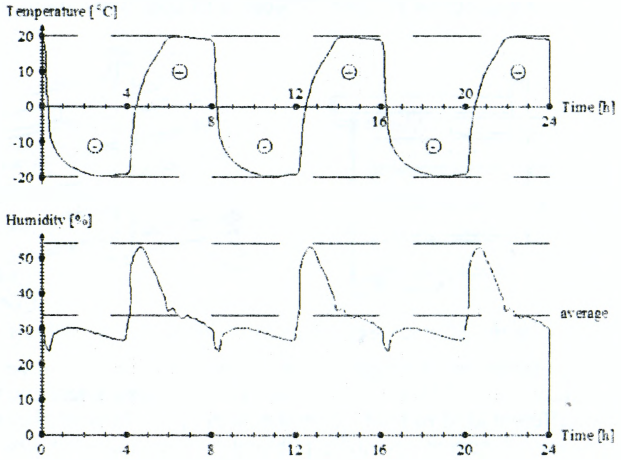

Figure 3 – Cyclic changes in temperature and humidity

The stands were located in the climatic room (with the working place of 2.0 x 3.0 m), allowing the temperature changes from -20 °C to +20°C in a 4-hour period (Fig. 3). Three stands were placed inside the climatic room, while the fourth - the reference one - was located outside the climatic chamber in room temperature. Two model beams were placed on every stand. The tested RC beams were subjected to the concentrated loading force of 3.50 kN passed on by the 7:1 lever ratio extension arms with the load of 0.50 kN placed on their ends (fig. 4).

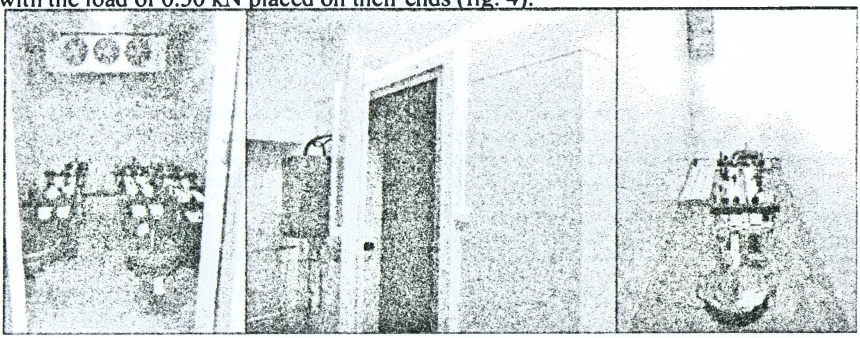

Figure 4 – The research stands with the model RC beams in the climatic room during the tests

The conducted research has been planned for 200 full cycles of freezing and thawing, with the continuous measurement of beams deflections (in the mid span and on the supports) using waterproof dial indicators. There were also measured concrete strains by the use of Demec extensometer in the mid span of the tested beams (see fig. 5). The program of a continuous research enclosed an initial measurement of concrete compressive strength, flexural strength and value of elasticity module, repeated for every 50 cycles.

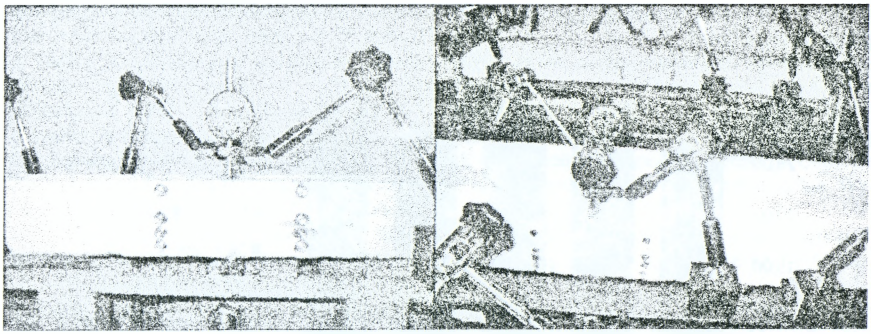

Figure 5 – Measurement of deflections and cracks

3. Chosen test results

In this paper the results of registered twenty-four-hour deflection changes of the RC model beams subjected to the static load equal to 560 kN combined with freezing/thawing cycles (in the case of beams located in the climatic room). The diagrams of beam deflections versus number of freezing/thawing cycles values are presented in Fig. 6 for beams made of RAC (series RW) and reference beams entirely made of natural aggregate concrete (Series SN).

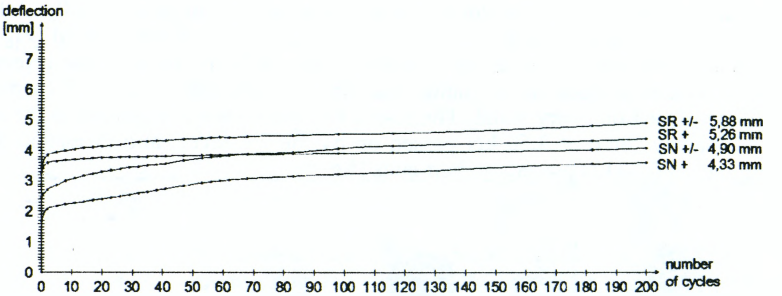

Figure 6 – Diagrams of the beams deflections versus number of cycles for the beam types: SR+/- and SN+/- (tested in climatic room) and reference beams SR + and SN+ (tested outside of climatic chamber in constant room temperature) - load equal 560 kN

Table 1 – Mean compressive strength of concrete [MPa] used in the tested beams after 95 days of curing in different temperature condition

Time of curing - Series of samples	28 days (room temperature)	95 days (constant room temperature)	95 days 200 cycles of freezing/thawing
normal concrete - Series SN	30,68	38,33 ↑ 25%	33,19 ↓ 13%
RAC - Series SR	31,20	43,13 ↑ 38%	35,64 ↓ 17%

After 95-days- curing of concrete samples in freezing/thawing conditions (after 200 cycles), the results of concrete compressive strength are presented in the Table 1.

It can be clearly seen the increase of concrete compressive strength obtained for samples kept 95 days in constant room temperature compared to the age of 28 days, whereas the samples located in the climatic room with freezing/thawing cycles revealed visible decrease in concrete compressive strength in comparison with reference samples.

The results of the elasticity module of concrete tests (repeated every 50 cycles) are given in the Figure 7.

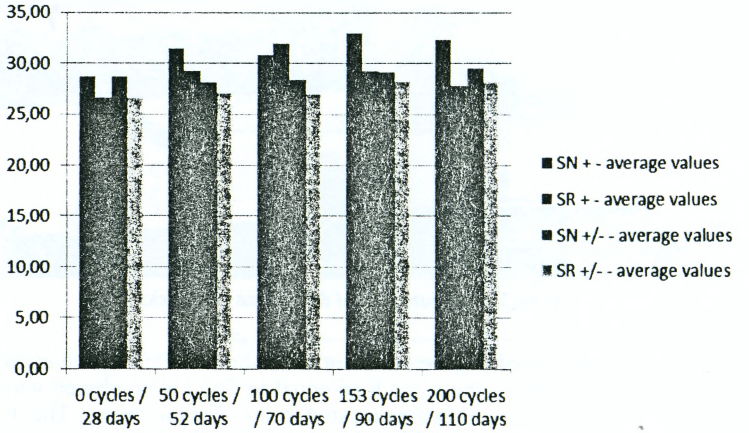

Figure 7 – Changes of module of elasticity of concrete [MPa] depending to number of freezing/thawing cycles

4. Conclusions

Achieved results so far are confirming the significant influence of interaction of static load and freezing/thawing cycles on RC beams deflections. The RC beams made of recycling aggregate concrete located in the climatic room with changing temperature have achieved much greater deflection values compared to analogical reference beams loaded outside climatic chamber in constant room temperature. This effect can be explained on the basis of decrease of beam stiffness due to destruction of concrete.

Current results as well as planned examinations will serve for creating guidelines for the use of recycled aggregate concrete (RAC) in structural elements taking into account the durability criterion depending on effects of RAC resistance against freezing and thawing cycles.

Both accepted technical solutions and procedures of examinations, as completely innovative, enclosed in submission to the patent register.

Acknowledgments

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REFERENCES

1. Ajdukiewicz, A. Properties of structural concretes with the recycling aggregates / A. Ajdukiewicz, A. Kliszczewicz // 58th National Scientific Conference. – Rzeszów - Krynica, 2012. – P. 173–180.

2. Council Directive 91/156/EEC (1991), amending Directive 75/442/EEC on waste.

3. Grygo, R. Modeling of RC precast composite beams made of recycled aggregate concrete strenghtened by HSC inserts / R. Grygo, A. Lapko, T. Chyży // Central Europe Towards Sustainable Building 2013: Sustainable building and refurbishment for next generations. – Praha, Czech Technical University, 2013. – P. 337–340.

4. Laoubi, K. (2006), Creep and durability of sand-coated glass FRP bars in concrete elements under freeze / Laoubi K., El-Salakawy E., Benmokrane B.thaw cycling and sustained loads. Cement and Concrete Composites, 2006. – P. 28:869–878.

5. Lapko, A. Modelling of freezing and thawing effects on the deflections or RC beams made of recycling aggregate concrete / A. Lapko, A. Baj // Modern materials, installations and construction technologies. – Państwowa Szkoła Wyższa im. Papieża Jana Pawła II, Biała Podlaska. – P. 28–35.

6. Lapko, A. Response of recycling aggregate concrete of RC beams under static load and freezing and thawing cycles / A. Lapko, A. Baj, R. Wasilczyk // 9th Central European Congress on Concrete Engineering: CCC 2013: Concrete Structures in Urban Areas. – Wrocław: Dolnośląskie Wydawnictwo Edukacyjne, 2013. – P. 324–327.

7. Lapko, A. Structural behaviour of RC flexural members made of recycling aggregate concrete: materialy V Mezdunarodnoy Konferencii „Aktualnye problemy Arhitektury i Stroitelstva" / A. Lapko, R. Grygo. – Sankt Petersburg, 2013. – Vol. 1. – P. 295–301.

8. Mu, R. Interaction between loading, freeze-thaw cycles, and chloride salt attack of concrete with and without steel fibre reinforcement. Cement and Concrete Research / R. Mu, C. Miao, X. Luo, W. Sun. – P. 1061–1066.

9. Rahal, K. Mechanical properties of concrete with recycled coarse aggregate. Building and Environment. – N 42 (1). – 2007. – P. 407–415.

10. Xiao, J. On statistical characteristics of the compressive strength of recycled aggregate concrete. Structural Concrete / J. Xiao, J. Li, Ch. Zhang. – N 12. – 2007. – P. 149–153.

11. Yao, Y. Durability of concrete under combined mechanical load and environmental actions: a review / Y. Yao, Z. Wang, L. Wang // Journal of Sustainable Cement-Based Materials. – Vol. 1, Nos. 1–2. – 2012. –P. 2–15.