

STRENGTH TESTS OF CONCRETE SPECIMEN EXPOSED TO AN AGGRESSIVE ENVIRONMENTS

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Abstract. *The paper presents the results of static tests of the concrete beams exposed to the aggressive environment in the agricultural building. The long-term effect of an aggressive environment was expected. The aim of analysis was to evaluate the condition of the ceiling panels. Static tests have provided information on the possible modulus of elasticity and the classes of concrete used to make the beams. The concrete beams with higher structure porosity and lower bulk density showed lower strength values and lower modulus of elasticity values. The knowledge gained from the analysis of beams will be used for comparison with the results obtained from the ceiling panels.*

Keywords

Strength tests, concrete specimen, aggressive environments, elastic modulus.

1. Introduction

Agricultural structures built in the second half of the past century in Slovakia nowadays show a high degree of degradation. This leads to the degradation of their static function and it is inevitable to monitor their condition. In order to eliminate degradation impacts, it is necessary to discover reasons of degradation and subsequently to design reconstruction methods. In the past, the research was carried out in this kind of buildings aimed at determining the static properties of ceiling panels [7], which is followed by the experiment described in this paper.

The aim of the original experiment was to evaluate the condition of ceiling panels of K-174 cow-barn structure and to design suitable rehabilitation provisions. In order to evaluate an impact of the aggressive environment, during construction of the cow-barn concrete beams made of

various concrete classes were placed into sky-lights to be later analysed for chemical degradation and its impact onto the concrete structure. The original formulation of the concrete mixture is not available, therefore after 27-year-long exposition, the concrete beams were also tested for strength to compare contents of chemical substances in specimen made of different concrete classes. Static tests results were evaluated in accordance with chemical analysis and were also compared with results obtained from the existing panel fragments.

Strength tests performed on concrete beams were confronted with chemical analysis results. Based on comparison of aggressive chemicals contents (chlorides, nitrates, ammonium salts, sulphates) between the beams and ceiling panel fragments, and measurements of proved strengths and Elastic moduli in the beams, it can be stated that high-strength concrete is as susceptible to aggressive substance penetration as low-strength concrete. High-strength concrete is not a guarantee of a lower content of unfavourable substances in a structure. This results in necessity to regularly monitor a structure of any kind of concrete placed in an aggressive environment, to monitor chemical substances increase, and to evaluate their impact on the structure. Based on the obtained data, it is inevitable to provide its maintenance and/or reconstruction.

2. Preparation of the experiment

Preparation of the experiment with concrete beams of 40 x 40 x 160 mm dimensions is described in [2]. One of the parameters for beam classification was the original specimen marking indicating which specimen had been made of the same concrete mixture batch. Strength tests were, besides others, supposed to signify what kind of concrete the specimen had been made of. In terms of classification into groups were the appearance, degree of damage, and surface structure. Specimen were classified into *twelve specimen groups, reinforced and non-*

reinforced, meeting requirements of the standard [3]. The specimens were marked 1a to 12b with approximate dimensions 40 mm x 40 mm x 160 mm, as specified in detail in [2], and subsequently they were measured and weighed (Fig. 1).

The most of the specimens showed a rigid structure (1a - 5b), a smaller part had a porous structure (6a - 7c, 12a - 12b), specimens with markings from 1a - 7c and specimens 12a - 12b were without reinforcement, specimens with markings from 8a - 11b were reinforced with a single 5.5 mm diameter rod for later assessment of reinforcement corrosion. From a visual point of view, the specimens did not show visible damage on their surface, as evidenced by the photo documentation, but the color of the surface and the odor indicated chemical contamination.

3. Strength tests

The static parameters of the specimens were not known, we carried out tests leading to their specification. The specimens suit requirements of standard [3]. The strength tests were carried out in a laboratory of Engineering Structures Institute of the Faculty of Civil Engineering, Technical University, Košice. Two press machines, Compression Testing Machine 3000 kN Capacity and ADR ELE 2000, were used for testing. The measured and calculated values, as well as monitored failure modes while pressing the specimens were recorded in tables [2].



Fig. 1: The specimen groups and measurement.



Fig. 2: Destruction tests and measurement of elastic modulus.

The following static tests were designed and carried out:

3.1. Concrete compressive strength specification

Each specimen was put in the centre between the pressing machine plates (Fig. 2). The specimens were pressed without shocks, and continuously up to their failure.

3.2. Specification of concrete static compressive elastic modulus

Elastic modulus is considered a fundamental property of concrete. As stated by authors in [5], Elastic modulus has a significant influence on concrete deformation properties, and thus subsequently affects deformation properties of concrete structures. The test was performed on non-

reinforced specimens. Measurements were carried out in accordance with the standard [4].

3.3. Specification of concrete bending tensile strength

The **flexural tensile strength test** performed on the test beams had a three-point arrangement. The test was performed on the remaining specimens of all groups (1a - 12b). A control measurement was also performed on specimen 1e in the Laboratory of Materials and Environmental Engineering on the ADR ELE 2000 test press with a prism attachment to compare the results. The measurements on both presses corresponded to each other. The test was performed by loading with one load (Fig.3), according to [4].

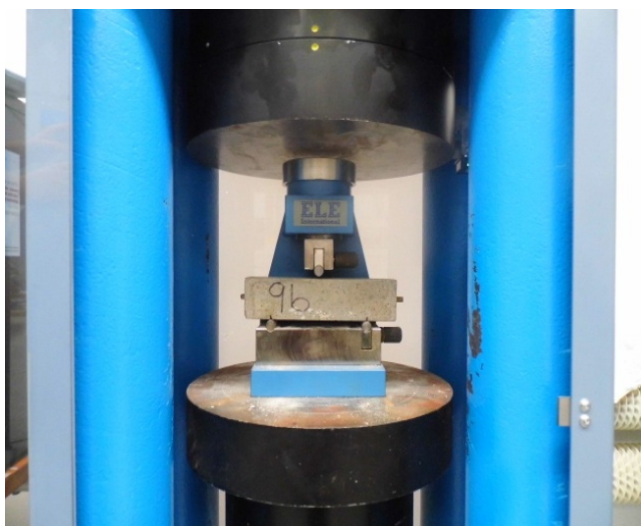


Fig. 3: Determining the tensile strength of the bending concrete.



3.4. Specification of compressive strength on beam fragments

To perform the test, a preparation marked EI 70 was used to determine the exact compressed square-shaped areas opposite to each other. The compressed areas for 40 x 40 x 160 mm prisms are 40 x 40 mm. The specimens were loaded up to their failure. The maximum force F [kN] and the stress σ [MPa] obtained at the specimen failure were recorded, while a failure mode of each specimen was monitored (Fig. 5).

4. Strength tests results and analysis

Since the beam's formulation was unknown, it was not possible to calculate compressive strength, and thus it was impossible to compare the compressive strength obtained by the static test with the standard one. It can be assumed

that the concrete beams, with regards to production faults, their age (they were made in 1987), 27-year-long storage in the structure, and a degradation degree, might suffer from a decrease in assumed compressive strength, and thus the strength obtained in the test may not necessarily correspond with the original compressive strength for the used concrete formulation. The measured results unambiguously prove that the concrete beams had been made of high-strength concrete.

From the viewpoint of Elastic modulus value measuring and calculating, it is obvious that specimens from basic groups 1 to 5 with Elastic modulus ranging from 26.78 GPa to 31.19 GPa belong to a high-strength concrete category which was also indicated by the specimen structure during their initial classification. Specimens from basic groups 6, 7 and 12 with Elastic modulus from 2.51 GPa to 6.06 GPa showed a porous structure, and thus a higher strength and Elastic modulus could not be expected. Measurements proved that Elastic modulus is influenced by the used type of aggregates.

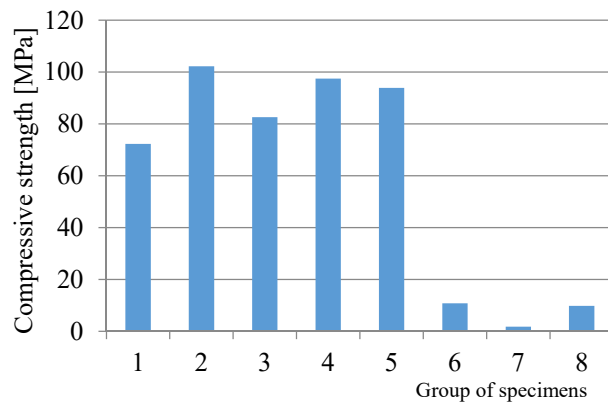


Fig. 4: Compressive strength of concrete of measured specimens.

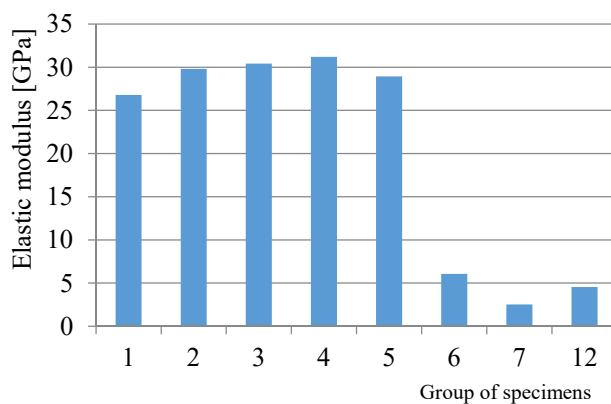


Fig. 5: Elasticity Modulus of measured specimens.

The test of bending tensile strength was performed on reinforced and non-reinforced beams, while the compressive strength test on fragments was carried out on beams without reinforcement. The results of the flexural tensile test - specimens without reinforcement show Tab. 2. The results obviously indicated the same conclusion as in the case of Elastic modulus measurements, i.e. the denser the specimen structure, the higher strength recorded. In some specimens, while testing for compressive strength on fragments, differences in values measured on the right and left

The fragments were too high which can be partially caused by imperfect compaction of concrete mixture in a formwork, but also by uneven specimen failure while testing for bending tensile strength. Since the specimens used in the tests were beams, not cubes, failure at compressive test could cause structural weakening in the right or left fragment, and thus the final values of compressive strength measured on fragments of the same specimen were, in some specimen groups, very different. Such results cannot be considered relevant, even though the test methodology and procedure were compliant with relevant standards.

Speciment	F [kN]	f_{cf} [MPa]
1d	7.72	18.1
1e	8.56	18.7
1f	9.01	21.1
1g	9.46	20.7
1h	9.14	20.0
2b	6.52	15.2
3b	6.51	15.2
3c	9.08	21.2
3d	7.14	16.7
4b	6.88	16.1
4c	8.35	19.5
4d	6.96	16.3
5b	7.35	17.2
6b	1.82	4.2
6c	2.16	5.0
7b	0.10	0.2
7c	0.10	0.2
12b	0.10	0.2

Tab. 1: The tensile test results: specimens without reinforcement.

5. Conclusion

Strength tests performed on concrete beams were confronted with chemical analysis results described in [1. 2. 6]. Based on comparison of aggressive chemicals contents (chlorides, nitrates, ammonium salts, sulphates) between the beams and ceiling panel fragments, and measurements of proved strengths and Elastic moduli in the beams, it can be stated that high-strength concrete is as susceptible to aggressive substance penetration as low-strength concrete. High-strength concrete is not a guarantee of a lower content of unfavourable substances in a structure. This results in necessity to regularly monitor a structure of any kind of concrete placed in an aggressive environment, to monitor chemical substances increase, and to evaluate their impact on the structure. Based on the obtained data, it is inevitable to provide its maintenance and/or reconstruction [8].

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References

- [1] PRIGANC, S.; and I. HEGEDŮSOVÁ. Assessment of the condition of ceiling panels in an aggressive environment. In: *Czech Journal of Civil Engineering*. 2015/2. ISSN 2336-7148.
- [2] HEGEDŮSOVÁ, I. and S. PRIGANC. *Analysis of concrete panel properties in aggressive environment*. TU – SvF 2015. ISBN 978-80-553-2312-1.
- [3] STN EN 12390-1: Testing of hardened concrete. Part 1: Shape, dimensions and other requirements for test specimens and molds. 2013.
- [4] STN EN 12390-4: Testing of hardened concrete. Part 4: Compressive strength. Testing machine requirements. 2001.
- [5] UNČÍK, S. ŠEVČÍK, P. The modulus of elasticity of concrete. Series of Beton racio. ISBN 978-80-969192-3-2.
- [6] PRIGANC, S. and E. TERPÁKOVÁ. *Diagnostics of concrete structure elements*. Košice. TU. SvF. 2003. ISBN 80-7099-937-3.
- [7] PRIGANC, S. and L. FECKO. *Determination of static properties of concrete support elements by tests*. Košice. TU SvF. 2012. ISBN 978-80-553-1263-7.
- [8] PRIGANC, S. and F. BAHLEDA. *Reinforcement of concrete elements*. Košice. TU SvF. 2006. ISBN 80-8073-589-1.

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