PERFORMING NON-DESTRUCTIVE EXAMINATIONS ON SLABS MADE OF STEEL FIBRE REINFORCED CONCRETE

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Abstract: Steel fiber reinforced concrete has been utilized as a construction material in the field of civil engineering on a regular basis for a prolonged period of time. Due to the fact that it possesses the appropriate qualities, steel fiber reinforced concrete is also used in the construction of certain protective structures in the field of military engineering. During the course of the past several years, non-destructive testing has emerged as the most prominent area of interest in the field of building diagnostics. Due to the fact that there is a complete absence of recognized methods and procedures that deal with the testing of fiber-reinforced concrete, numerous experiments have been conducted using conventional non-destructive methods with the intention of determining the applicability of these approaches to the testing of structural elements that are built from fiber-reinforced concrete. The article provides a description of an experiment in which the compression strengths of a material are compared using a destructive approach and a non-destructive method (hardness, ultrasonography).

Keywords-steel fibre reinforced concrete; non-destructive testing; Silver Schmidt hardness hammer; ultrasound measurement; compressive strength.

I. INTRODUTION

The non-destructive testing (NDT) is increasingly applied in civil engineering because of its advantages: non-destructive nature, repeatability and economical aspect. On the other hand, there is also a disadvantage that the NDT methods are indirect methods. The NDT methods mainly detect structural fluctuations, minor changes in surface quality, cracks or other physical imperfections.

Currently, there is a number of NDT methods that are suitable for the assessment of plain concrete or reinforced concrete but there are not any standards for classification of steel fibre reinforced concrete (SFRC). The SFRC as a building material has been used for several decades and its base, reinforcement by fibres, dates back to a deep history. Also in military engineering, selected protective structures are built from steel fibre reinforced concrete because of its suitable properties [1-9].

The production technology of SFRC is far more developed than the diagnostics methods of SFRC structures which cause several problems. The SFRC gets its unique properties, such as increased tensile strength after macro-crack formations and impact strength, due to the addition of steel fibres into plain concrete. Also the production technology of SFRC is not precisely described by technical standards which cause certain issues during the production of SFRC structures and structural elements. In recent years, the NDT methods for the quality control of SFRC structures have become the focus and object of scientific research activities of several research institutions around the world [10, 11].

There are several NDT methods that are already verified for the diagnostics of elements and structures, which are made from plain or reinforced concrete, but not all of them are suitable for the diagnostics of SFRC because of its special properties. As a result of an experiment, which was conducted at the Brno Technical University in cooperation with the University of Defence, two NDT methods were selected to evaluate the compressive strength of a SFRC structural elements. The compressive strength cannot be ranked among the main laboratory tests of SFRC since the addition of steel fibres to the concrete mixture does not significantly increase it. However, the requirement to verify the compressive strength of SFRC in-situ is not unusual. The destructive method, which is considered to be most reliable, consists of standard laboratory tests of several core boreholes taken directly from the structural elements.

Also the destructive method has its disadvantages as number of core boreholes and their position on the structural element is not precisely specified. To get the most reliable results of testing, the best option is to use the NDT method together with the destructive method. The ultrasound method and hardness method are the main NDT methods that can be used to estimate the compressive strength.

II. IMPLEMENTATION AND RESULTS

The experiment is based on the comparison of values of compressive strength that were obtained from two different methods: the destructive method (core boreholes) and the NDT method (hardness method and ultrasound method). The destructive test was carried out in accordance with the technical standard ČSN EN P 73 2452: Fibre reinforced concrete – Testing of hardened fibre-reinforced concrete [5].

Figure 1. Silver Schmidt hardness hammer

Figure 2. Pundit Lab Plus ultrasound device

Three slabs (D 1, D 2 and D 3), measuring 1000×1000×100 mm, were made from three SFRC mixture compositions varying in volume of steel fibres according to Tab. I.

TABLE I. SFRC MIXTURE COMPOSITIONS

SFRC Slab No.	Cement 42,5 R	Water	Water ratio	Aggregat e 0–16	Plasti-ficator	Steel fibres
[–]	[kg/m^3]	[kg/m^3]	[–]	[kg/m^3]	[kg/m^3]	[kg/m^3]
D 1	390	160	0.41	1820	4	40
D 2	390	160	0.41	1820	4	80
D 3	390	160	0.41	1820	4	120

There were nine measuring points on each slab and the measurements were made using both NDT methods, Fig. 3. At first, the slab was tested using a Silver Schmidt hardness hammer and around each measuring point, ten values were read to comply with the minimum number of seven measuring points required by the Czech technical standard ČSN 73 1373 – Non-destructive testing of concrete – Determination of compressive strength by hardness testing methods [4].

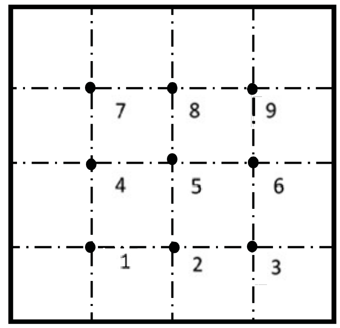

Figure 3. Nine measuring points on SFRC slab

Also another requirement set by the Czech technical standard ČSN 73 1373 [4] was verified: any of the values cannot differ from arithmetic mean more than ±20 %. The informative values of the compressive strength were determined from the calibration curves given in [10].

The calibration curves for plain concrete were used for the testing and the aim of the experiment was to verify their usability in the diagnostics of SFRC. After the evaluation of the measurement made by the Silver Schmidt hardness hammer, see Tab. II, it was revealed that the calibration curve does not have the required range to evaluate the compressive strength of SFRC. For this reason, another, more suitable, calibration curve "Lower 10th percentile curve" was selected from European technical standard EN 13791 [8], which gives methods and procedures for the assessment of the in-situ compressive strength of concrete in structures and precast concrete components. The range of the rebound coefficient was from 22 to 75 and the range of compressive strength was from 8 MPa to 100 MPa.

TABLE II. INFORMATIVE COMPRESSIVE STRENGTH FROM SILVER SCHMIDT HARDNESS HAMMER

SFRC Slab No.	Average Rebound Coefficient	Average Standard Deviation	Informative Compressive Strength
[–]	[–]	[–]	[MPa]
D 1	65	2.61	65.4
D 2	68	2.91	74.5
D 3	67	2.72	70.9

In the second step of the experiment, the ultrasound device was used to take measurements in nine measuring points on each SFRC slab. In order to eliminate error measurement, each point was measured three times in accordance with Czech technical standard ČSN 73 1371 [3]. Based on the thickness of the SFRC slab, the velocity of ultrasound propagation and its arithmetic average were calculated.

To compare and validate the results obtained from two NDT methods, the destructive method was used and nine core boreholes were taken from each concrete slab in measuring points according to Fig. 3. In total, 27 core boreholes from all slabs were removed, Fig. 4.

Figure 4. Removal of core borehole from concrete slab

The comparison of results obtained by a non-destructive method (hardness, ultrasound) and by a destructive method is shown in Fig. 5.

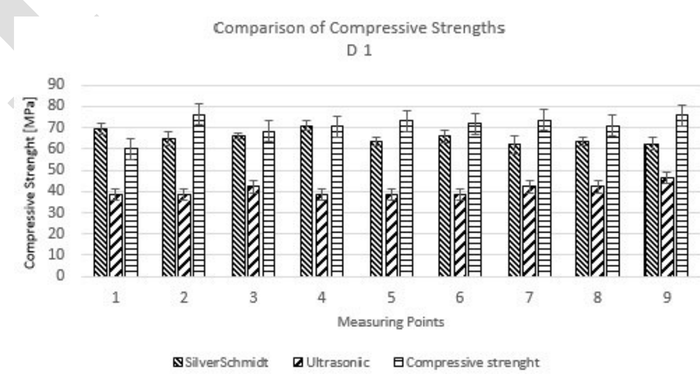

Figure 5. Comparison of compressive strength values on the slab D 1

The informative values of the compressive strength determined by the hardness method are almost double the values determined by the ultrasound method. Based on the comparison of results, it could be concluded that ultrasound method is not suitable for the assessment of the compressive strength of SFRC structural elements using the calibration.

III. CONCLUSION

The experiment, which was carried out by the Brno Technical University and the University of Defence, was focused on non-destructive diagnostic methods applicable to the structures build from the steel fibre reinforced concrete. The aim of the experiment was to verify the applicability of selected non-destructive methods for the SFRC structural elements. The precise methods are described in detail in the technical standards as they should be applied to plain concrete and reinforced concrete. The results show that further testing isneeded. The testing should be focused on finding calibration curves specifically for the building material of SFRC. The future research in this area should be focused the on developing a new method using Silver Schmidt hardness hammer for determining the compressive strength of steel fibre reinforced concrete.

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