20th International Conference
ENGINEERING MECHANICS 2014
Svratka, Czech Republic, 12 – 15 May 2014

THE INFLUENCE OF FROST RESISTANCE ON UHPC PLATES WITH DIFFERENT TYPES OF TEXTILES ARMATURES

M. Kostelecká*, J. Kolísko, T. Bittner**, P. Huňka**, T. Mandlík****

Abstract: *High strength concrete and ultrahigh performance concrete (UHPC) develops quickly and applications appear in many countries. The UHPC are high performance concretes with exceedingly high strengths and durability. These materials include Portland cement, silica fume, quartz flour, fine silica sand, high-range water-reducer, water and either steel or organic fibres. Depending on the type of fibres used can influence the compressive strength. The article describes the tests of frost resistance on UHPC plates with different types of textiles armatures, such as referential matrix without armature, 3D glass fabric, PVA fibres and glass fibre mesh fabric. The aim of the testing is describe influence of textiles armatures in UHPC matrix in extreme conditions. These conditions are typical by practical use of UHPC for architectural building panels.*

Keywords: UHPC concrete, Textiles armatures, Frost resistance, Bending strength, Plates.

1. Introduction

UHPC (Ultra High Performance Concretes) are ultra high-grade concretes with fine-grained macrostructure and high consistency. This implies its high resistance to the penetration of liquids and high durability. Due to its high compression strength greater than 150 MPa and improved durability, these represent significant advances in concrete technology. This highly advanced and sophisticated material offers a number of interesting applications such as the production of facade panels, which promotes more abroad. In this article the frost test is presented on thin UHPC slabs that are reinforced by a new type of armature. It is a textile armature, which should replace the classic metal (steel) armature. Textile armature should not only reduce the cost of production, but, because it is not susceptible to corrosion as conventional steel armature, panels can be designed with significantly less cover thickness in achieving similar or longer lifetime of these elements. The combination of UHPC concrete with a minimum thickness of cover and textile armature allows to design elements weighing up to 70 % lower compared to conventional concrete elements with conventional armature. This can achieve significant savings and benefits not only in economic aspects, but also in environmental aspects (Novotná et al., 2013).

2. Test Specimens

The four concrete test plates with sizes 700 x 250 x 15 mm were produced for comparative experiments (see Fig. 1) on May 20, 2013. All four plates were made from the same type UHPC with similar recipe matrix. The difference was only in the type of textile armature.

The recipe matrix for 1 cubic meter did consist: cement CEM I 52.5 N – white (650 kg), calcite + TiO2 (132 kg), sand +milled silica, max. fraction 1.6 mm (1264 kg), water (164 kg), superplasticizer (37.6 kg).

The first plate was without armature (marked M), the second one contain PVA fibres with length 20 mm (marked PVA). The third plate use alkali-resistant glass fibre mesh fabric with mesh dimension 5 mm (marked Perl). The last one contains the 3D glass alkali-resistant armature with mesh dimension 20 mm (marked 3D).

* Ing. Michaela Kostelecká.: Klokner Institute, Czech Technical University in Prague, Šolínova 7, 166 08, Prague; CZ, michaela.kostelecka@klok.cvut.cz

** Assoc. Prof. Ing. Jiří Kolísko, PhD., Ing. Tomáš Bittner, Ing. Petr Huňka, Ing. Tomáš Mandlík: Klokner Institute, Czech Technical University in Prague, Šolínova 7, 166 08, Prague; CZ, {name.surname}@klok.cvut.cz

Each plate was further cut into 6 smaller test plate specimens with dimensions: width 124 mm, length 232 mm and thickness 13 mm. A set of 6 test specimens was created from one plate with the specific type of armature. There were thus prepared 24 test specimens. Half of them were then subjected to cycles of freezing, half served as a reference.

Basic characteristics of the used materials are: for the matrix without armature and matrix reinforced by glass fibre mesh armature and 3D glass fabric armature tested on solids wit dimensions 40 x 40 x 160 mm after 28 days of ageing, the compressive strength was 125 MPa, a bending strength was 19 MPa and a volume weight was 2410 kg/m^3. For the matrix with PVA fibres the solid of the same size and age the compressive strength was 112 MPa, bending strength was 25 MPa and a volume weight was 2400 kg/m^3.

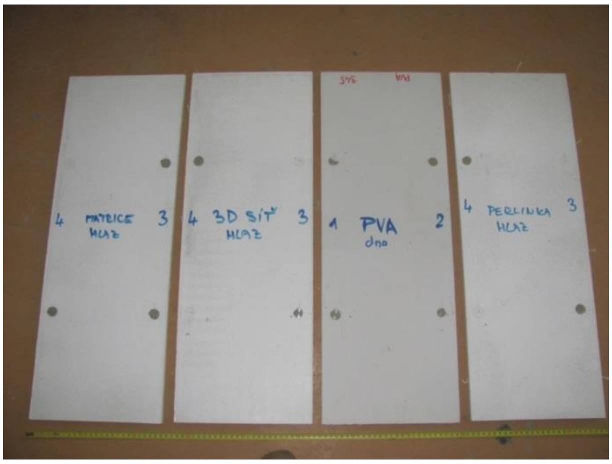

Fig. 1: UHPC plates with (from left) – referential matrix without armature, 3D glass fabric, PVA fibres, glass fibre mesh fabric.

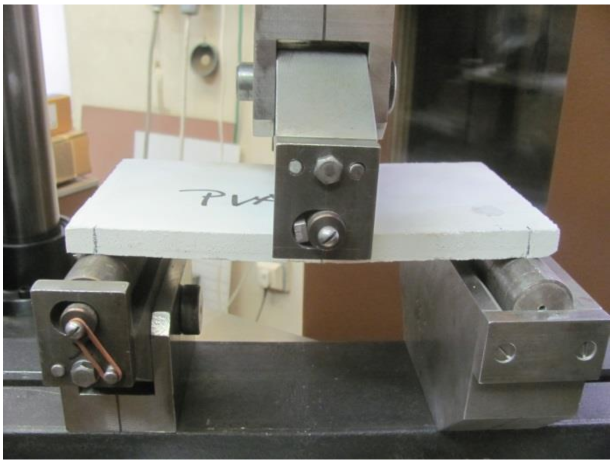

Fig. 2: Testing device for bending strength TIRATEST 2300 during test.

3. Procedure of Monitoring the Frost Resistance Test

The purpose of this test was to specify tensile strength when bending the testing samples by selected freezing cycles.

The bending strength was determined according standard ČSN EN 12467 in three-point bending strength.

The tests were performed on the test device TIRATEST 2300 (see Fig. 2). The support distance was 200 mm. The rate of loading of specimens was 1 mm/min, the rupture did occur in time between 10 and 30 seconds.

Results were determined by comparing the two sets of samples:

- 1. set – unexposed (reference) testing plates after storage in water at 20 ± 2 ° C,
- 2. set – exposed testing plates after cycling – 2 hours freezing in -20 ± 4 ° C and 2 hours defrosting in water 20 ± 4 ° C.

The cycling was done automatically in a freezing chamber. After the required number of 150 cycles, the testing samples were conditioned in the water 20 ± 2 ° C during 7 days. Subsequently, the bending test was carried out (ČSN EN 12467, 2005; ČSN EN 1170-5, 1999; Kostelecká et al., 2013).

4. Results of Comparative Experiment

A summary of the results of mechanical tests are shown in Tab. 1 and in Figs. 3 a 4.

Tab. 1: Coefficient of frost resistance and the average of bending strength determined at the reference set of specimens (1 set) and set of frozen samples after 150 cycles (2 set).

Specimens	**Volume weight [kg/m³]**	**MOR_f [MPa]**
Specimens without armature - marked M – average from three tests		
specimens M – reference	2437	14.6
specimens M – after freezing	2459	12.8
Coefficient of frost resistance - specimens M – ratio of bend. strength		**0.9**
Specimens with PVA fibres armature – marked PVA – average from three tests		
specimens PVA – reference	2363	14.4
specimens PVA – after freezing	2464	13.9
Coefficient of frost resistance - specimens PVA – ratio of bend. str.		**1.1**
Specimens with glass fibre mesh fabric armature – marked Perl – average from three tests		
specimens Perl – reference	2472	12.7
specimens Perl – after freezing	2415	11.4
Coefficient of frost resistance - specimens Perl – ratio of bend. str.		**0.9**
Specimens with 3D glass fabric armature – marked 3D – average from three tests		
specimens 3D – reference	2392	19.0
specimens 3D – after freezing	2335	14.0
Coefficient of frost resistance - specimens 3D – ratio of bend. str.		**0.7**

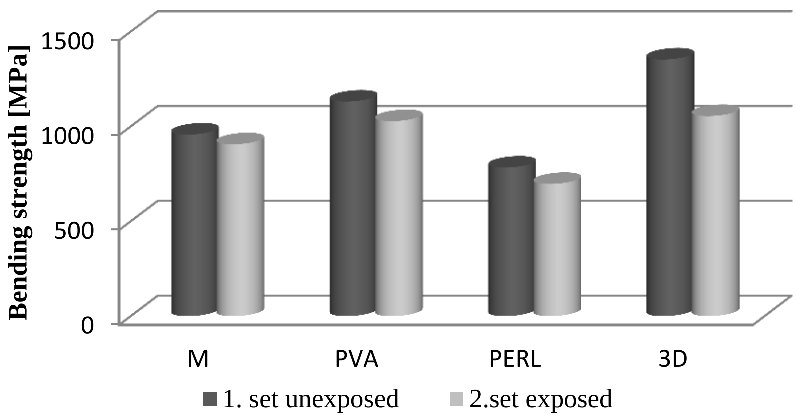

Fig. 3: The frost resistance test – comparison of average values of bending strength.

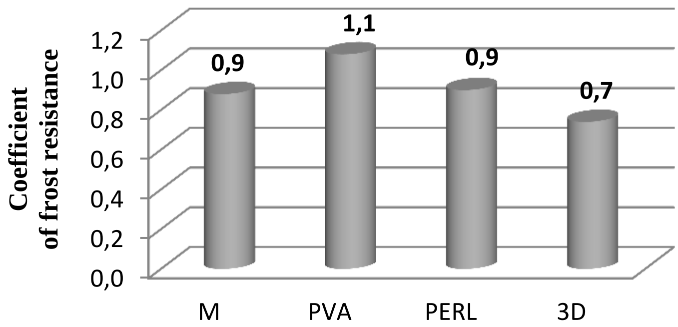

Fig. 4: Coefficient of frost resistance-the ratio of bending strength (of both set 1+2).

The results of tests of frost resistance of thin UHPC plates were presented in this article. The UHPC plates were reinforced with different types of textile armatures: PVA fibres, glass fibre mesh fabric and 3D glass fabric. Each type of test samples was divided into two sets. First set contained unexposed (reference) samples (7 days conditioning in water at 20 ± 4 ° C). The second set contained samples exposed (cycling two hours of freezing at -20 ± 4 ° C and 2 hours of putting into water at 20 ± 4 ° C in 150 cycles and after 7 days conditioning in water at 20 ± 4 ° C). Results were determined by comparison of the two sets of test specimens.

From the measured values we can see that the greatest strength values were obtained for samples with 3D glass fabric armature, then the samples reinforced with PVA fibres and the lowest values were obtained for samples with glass fibre mesh armature. The bending strength of samples with 3D glass fabric armature and PVA fibres armature were higher than the strength of the matrix without armature. For specimens with 3D glass fabric armature was bending strength higher by 37 %, and samples with PVA fibres armature by 15 %. Only samples reinforced with glass fiber mesh reached a lower bending strength values than the matrix without armature by 21 %.

When we compare exposed and unexposed sets, the exposed sets have lower strength values, but the differences are not so significant. The differences are 28% for 3D glass fabric armature, 10% for PVA fibres armature, 11% for glass fibre mesh armature and 5% for the matrix without armature. The value of 28 % for 3D specimens could be lower. The problem was with 3D specimen No. 1, which was mechanically damaged when cycling in the laboratory.

5. Conclusions

The presented results indicate that the greatest strength values were obtained for the test plates reinforced with 3D glass fabric armature. From this it follows that the best use of unconventional textile armature is a 3D glass fabric armature. The advantage of this armature is its alkali-resistance against aggressive environments. The disadvantage is that it is most expensive of all of the tested textile armatures.

Acknowledgement

The research has been supported by the Grant Agency of the Czech Republic No. 13-12676S.

References

ČSN EN 1170-5(1999) Precast concrete product – Test method for glass-fibre reinforced cement – Part 5: Measuring bending strength, "Complete bending test" method.

ČSN EN 12467 (2005) Fibre-cement flat sheets – Product specification and test methods.

Kostelecká, M., Kytýř, D., Doktor, T. (2013) Study of Degradation of Fibre – Cement Plates with Different Types of non-Metalic Fibres, in: 10th Youth Symposium on Experimental Solid Mechanics, Technische Universitat Chemnitz, Chemnitz, pp. 61-62, ISBN 978-3-941003-34-7.

Novotná, M., Kostelecká, M., Hodková, J., Vokáč, M. (2013) Use of Textiles Reinforced Concrete – Especially for Façade Panels, In: CRRB-15th International Conference on Rehabilitation and Reconstruction of Building, Vědeckotechnická společnost pro sanace staveb a péči o památky, Prague, pp. 264, ISBN 978-80-02-02502-3.