53rd Conference on Experimental Stress Analysis
Český Krumlov, Czech Republic, June 1–4, 2015 

# Application of AR-Glass Fabric and Cement Matrix for Strengthening Bending Concrete Elements

O. Holčapek [1,2,*]

[1] *CTU in Prague, Faculty of Civil Engineering, Experimental Centre, Thákurova 7, 166 29 Prague 6, Czech Republic*

[2] *CTU in Prague, University Centre for Energy Efficient Buildings, Třinecká 1024, 273 43 Buštěhrad, Czech Republic*

[*] *ondrej.holcapek@fsv.cvut.cz*

**Abstract:** This paper focuses on possible application of newly developed textile reinforced cement matrix for strengthening load-bearing structure elements from concrete. One year old concrete beams $100 \times 100 \times 400$ mm made from ordinary concrete C 25/30 have been used for verification of possible application of this matrix and glass fabric for strengthening. Fine grain concrete with compressive strength over 100 MPa with maximum grain size 1.2 mm and water-binder ration 0.29 was used. The aim of performed experimental program is to evaluate the influence of various number of alkali-resistant (AR) glass fabrics (1, 3, and 5 layers) applied on bending side. The cohesion of concrete surface layer with the newly applied slim surface of textile reinforced concrete has been approved.

**Keywords:** AR-Glass Fabric; Old Concrete; Fine Grain Cement Matrix; Strengthening; Textile Reinforced Concrete; Bending Test.

## 1 Introduction

Strengthening of existing load-bearing structures is complex system of technological aspects, static and dynamic analysis, material sciences, historical and structural survey, etc. The incoming characteristics of original materials have to be investigated, usually by destructive or non-destructive (e.g. dynamic modulus of elasticity [1], moisture, etc.) methods. Originally used methods (steel bandage or additional concrete layer) are replacing by newly developed materials and technologies like CFRP or GFRP fabric in combination with epoxy paste. Especially the GFRP materials are suitable for various types of structures (concrete, masonry or timber) [2]. It is always necessary to consider the way and material for strengthening according to type of acting load. Newly developed ultra-high performance concrete (reinforced by high dosage of steel fibers with strength over 1500 MPa) is successfully used for reconstruction and strengthening of existing concrete structures. Work [3] describes practical use of this composite for strengthening reinforced concrete columns over 80 years old.

Significant progress in the field of textile reinforced concrete (TRC) has been achieved last decade. From the first research works and laboratory applications the current technical and practical applications are performed. The cement matrix, especially in the case of high steel fibers dosage, is characterized by excellent mechanical properties (strength, modulus of elasticity, fracture energy, etc.) [4, 5] and achieve high strength in very early after production. We can find the application of TRC in the façade panels, protective slabs [6] or pre-cast loadbearing elements for architectural remarkable structures production. Progressive utilization of TRC leads in the strengthening of existing concrete load-bearing elements. Brückner in [7] performed the first experiments aimed on possible application of TRC (carbon fabric) for strengthening bending reinforced concrete slabs (T-shape). Experimental and numerical analysis of bending load capacity of reinforced concrete slabs strengthened with carbon textile performed Schladitz in [8]. Contamine in [9] examined the strengthening of reinforced concrete girder by TRC (AR-glass textile reinforcement). The behavior of girder is different from slabs, especially due shearing force near support. The strengthening on bending side resists bending moment (tensile tension) and the additional strengthening layer on both lateral sides near supports resist shearing force.

Tab. 1: Composition of used mixtures.

| Components | C 25/30 [kg m$^{-3}$] | CM [kg m$^{-3}$] |
|---|---|---|
| CEM 42.5 R | 300 | 680 |
| Microsilica | - | 129 |
| Silica Powder | - | 326 |
| Sand 0.1/0.6 | - | 326 |
| Sand 0.3/0.8 | - | 340 |
| Sand 0.6/1.2 | - | 258 |
| Sand 0/4 | 893 | - |
| Aggregate 4/8 | 390 | - |
| Aggregate 8/16 | 800 | - |
| Water | 187 | 238 |
| Plasticizer SVC | - | 6.8 |

## 2 Experimental Program

One year old beams 100 × 100 × 400 mm made from concrete C25/30 have been used for the experimental program purpose. This concrete beams were stored in ordinary laboratory conditions (relative humidity 50 % and temperature 20 ± 3 °C). Slim layer of fine grain concrete (approximately 5 mm) contained different amount of AR-glass fabric (1, 3 and 5 layers with dimension 100 × 300 mm) was applied as the strengthening. Rapid mechanical properties growth is typical for this type of cement matrix and has been investigated in [10]. Used fabric is characterized by 275 g/m$^2$ and we can be seen on Fig. 1. Strengthened samples were stored in laboratory conditions and the testing of final strength took place after 28 days. Three specimens with each number of textile layers (0, 1, 3 and 5) were produced and tested (totally 12 beams). Tab. 1 shows composition of used concrete and fine grain concrete.

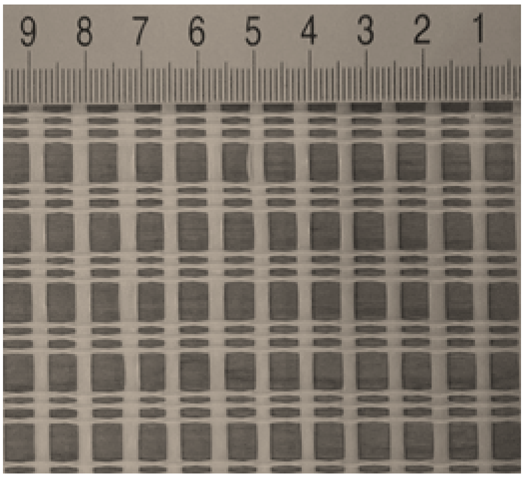


Fig. 1: Used AR-glass textile.

### 2.1 Strengthening Process

Firstly the surface of concrete beams were roughened by steel brush and pre-wetted by spraying to ensure the cohesion of old and newly applied layers. First layer of glass fabric with dimension 300 × 100 mm was impressed into 2 mm of cement matrix. Onto glass fabric slim layer of cement matrix was applied and into it the other glass fabric reinforcement. The last layer is always cement matrix. Slim layer of cement matrix and basalt fabric was applied on lateral sides of specimens. The process of strengthening can be seen on

Tab. 2: Compressive strength of used concrete and cement matrix (CM) for strengthening.

| | Compressive strength $f_c$ [MPa] in various ages | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 day | 2 days | 7 days | 14 days | 28 days | At strengthening | At testing |
| C 25/30 | 11.5 | 19.8 | 28.6 | 36.7 | 39.9 | 43.1 | 43.4 |
| CM | 23.5 | 61.2 | 77.1 | 95.0 | 101.2 | - | 102.4 |

Tab. 3: Measured and calculated data from destructive testing of strengthened samples.

| Number of textile layers | Thickness [mm] | Maximum force [kN] | Tensile strength during failure [MPa] |
|---|---|---|---|
| Non-strengthened | 0 | 17.1 | 5.1 |
| 1 | 4.0 | 27.5 | 7.9 |
| 3 | 5.6 | 53.2 | 15.2 |
| 5 | 6.2 | 66.0 | 18.7 |

Fig. 2. The concrete beam with slim layer of textile reinforced concrete was wrapped into non-breathable foil for 48 hours. Storage took place in laboratory conditions till the age 28 days, where the destructive bending tests were performed. Compressive strength of used cement mixture and ordinary concrete in various ages are shown in Tab. 1 (especially strength during strengthening process and during bending test of strengthened specimens). Compressive strength of ordinary concrete was measured on standard cube specimens with dimension 150 × 150 × 150 mm on EBD400 device. The compressive strength of cement matrix (CM) for textile reinforced concrete production was examined by INOVA device and the measurement took place on cube specimens with dimension 100 × 100 × 100 mm.

### 2.2 Testing of Mechanical Properties

The test was arrangement as four-points bending test with clear span of supports 300 mm. Measurement system DEWE-30-16 received signal from DTA 10 inductive displacement transducer and force sensor PS200. The displacement transducer was placed directly on special facility fixed on testing sample. This arrangement eliminates pushing support and only deflection of testing beam is measured. The test was controlled by increase of deformation with loading speed 1.0 mm/min by loading system from INOVA.

## 3 Results

Tab. 2 summarizes measured and calculated data from performed experimental testing of strengthened concrete beams with dimension 100 × 100 × 400 mm. Thickness of strengthened layers grows with increasing number of used textiles and is shown in third column of Tab. 2. The values of strengthened layers thickness was measured on fragments after bending test in the middle span on cross-section made by chop saw. The maximum force grows with number of used textile layers but it is limited by shearing load capacity.

## 4 Conclusion

Performed experimental program confirmed the suitability of newly developed textile reinforced concrete for strengthening existing bending concrete structures. The transport zone between surface layer of old ordinary concrete and newly applied slim layer of cement matrix reinforce by alkali resistant glass textile showed excellent properties during bending test. This is the basic premises for successful application of this cement composite for strengthening bending load-bearing elements in general. Application of one or three layers of textile fabric resulted into bending breakdown of specimens, while application of five layers on ordinary concrete beam (without steel reinforcement) resulted into different failure mode due the shearing force (see Fig. 3).

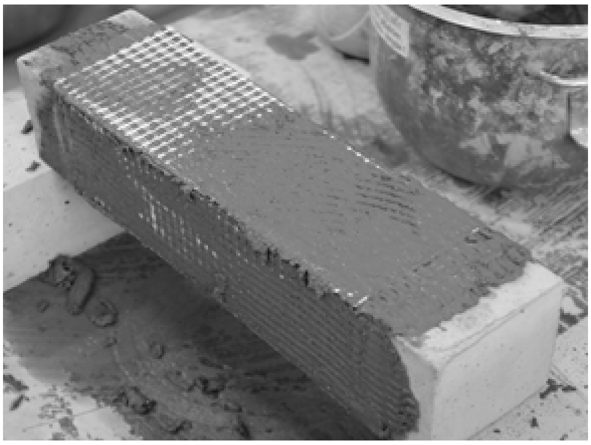

Fig. 2: Strengthening process.

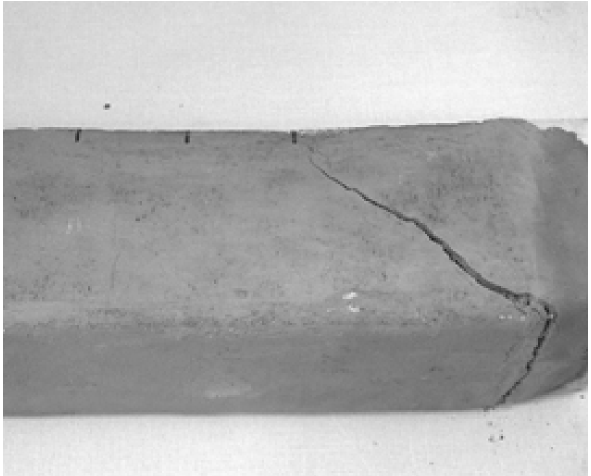

Fig. 3: Crack due action of shearing force.

We can observe share cracks (angle 45 degrees) formed near support. The formation of shearing breakdown is given by absence of shearing steel reinforcement in tested specimen. If the samples had shearing steel reinforcement (which is typical for real structures) the bending capacity of strengthened concrete element will be higher and the applicability of used textile fabric will be on maximum level. The maximum effectiveness is achieved in the case of strengthening bending reinforced concrete elements (slabs or beams).

Strengthening of existing concrete structure by slim layer of textile reinforced concrete has great potential for real application in practice. Future research will focused on large-scale experiments, where reinforced concrete beams with length 1500 mm will be strengthening.

## Acknowledgement

This research work was financially supported by European Union, OP RDI project No., CZ.1.05./2.1.00/ 03.0091 – University Centre for Energy Efficient Buildings and by CTU project No., SGS13/165/OHK1/3T/11 – Pozzolana active materials as a partial replacement of cement in concrete which is gratefully acknowledge.

## References

[1] T. Pavlů, M. Šefflová, The static and the dynamic modulus of elasticity of recycled aggregate concrete, Advanced Materials Research 1054 (2014) 221-226, doi: 10.4028/www.scientific.net/AMR.1054.221.

[2] J. Witzany, T. Čejka, R. Zigler, Failure mechanism of compressed short brick masonry columns confirmed with FRP strips, Construction and Building Materials 63 (2014) 180-188, doi: 10.1016/j.conbuildmat.2014.04.041.

[3] D. Rosignoli et al, Structural Reinforcement and Seismic Retrofitting with UHPFRCC Special Formulation Jacketing of 1930 Building RC Structural Elements, in proc.: The 4$^{th}$ International FIB Congress (2014), Mumbai, 20014.

[4] P. Reiterman et al, Development and Mix Design of HPC and UHPFRC, Advanced Materials Research 982 (2014) 59-62, doi: 10.4028/www.scientific.net/AMR.982.130.

[5] M. Tvarog, J. Fornůsek, Influence of Casting Direction the Mechanical Properties of Cementitious Fiber Reinforced Composites, Advanced Materials Research 982 (2014) 32-37, doi: 10.4028/www.scientific.net/AMR.982.32.

[6] F. Vogel, Production and Use of the Textile Reinforced Concrete, Advanced Materials Research 982 (2014) 59-62, doi: 10.4028/www.scientific.net/AMR.982.59..

[7] A. Brückner et al, Textile reinforced concrete for strengthening in bending and shear, Materials and Structures 39 (2006) 741-748, doi: 10.1617/s11527-005-9027-2.

[8] F. Schlading et al, Bending load capacity of reinforced concrete slabs strengthened with textile reinforced concrete, Engineering Structures 40 (2012) 317-326, doi: 10.1016/j.engstruct.2012.02.029.

[9] R. Contamine, S. A. Larbi, P. Hamelin, Identifying the contributing mechanisms of textile reinforced concrete (TRC) in the case of shear repairing damage and reinforce concrete beams, Engineering Structures 46 (2013) 447-458, doi: 10.1016/j.engstruct.2012.07.024.

[10] F. Vogel, O. Holčapek, P. Konvalinka, Study of the strength development of the cement matrix for textile reinforced concrete, Advanced Materials Research 1054 (2014) 99-103, doi: 10.4028/www.scientific.net/AMR.1054.99.