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Influence of Penetrated Roving Surface Treatment on the Crack Width Using Pull-out Test

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Abstract. This paper presents the possibility and suitability of chosen pull-out test method in the case of surface treatment using fine grain technical silica sand. Surface treatments in general significantly improve bond between composite reinforcement and cement matrix and thereby the effectiveness of roving single fibers. The specimen according to used testing method has a small thickness 6 mm. The advantage is that concrete cover less than 3 mm corresponds to concrete cover in real structures. But this cover is double side around one layer of reinforcement and in structures this situation does not occur. The disadvantage is that by the bond parameters improving specimens were damaged in their concrete part much before reaching the maximum force required for the reinforcement break.

Introduction

With the development of high performance concretes (HPC) [1] come also demands for some new noncorrosive materials as reinforcement in extremely subtle structures with similar or better mechanical parameters compared to the conventional steel reinforcement. For this reason technical textiles began to be more and more popular. They use most commonly carbon, AR-Glass and basalt roving penetrated with polymer matrix. It is a relatively new composite material which is different from the traditional steel reinforcement also in the case of interaction with the cement matrix. In the past many numerical studies were created with influence of cohesion [2]–[4]. Aim of this presented study is to show the difference in results of pull-out test with and without surface treatments of penetrated roving using selected testing method. It was also investigated the effect of filler added into the epoxy resin matrix on bond behavior and controlled crack width.

Testing methodology and set-up

The testing methodology was inspired by [5] with unsymmetrical anchoring length. On one side of the specimen a penetrated roving pull-out was secured using the short length 20 mm. On the opposite side was penetrated roving anchored along the remaining length of the HPC specimen. Specimen dimensions and also testing set-up are clearly presented in Fig. 1. The HPC plate with dimensions of 60 x 278 mm has a thickness of only 6 mm. The only one penetrated roving using epoxy resin was embedded in HPC specimen matrix in its axis. HPC recipe and its basic mechanical parameters, mechanical parameters of used AR-Glass roving and parameters of used epoxy resin matrix are listed in [6], [7]. It was used the same material in order to comparison of obtained results with previous research. Surface treatment was done using technical silica sand with grain size 0.1 – 0.6 mm. As filler into epoxy matrix Stellmittel T (Extender F) from the Sika Company was used. Four sets of specimens including five pieces for each group were created. The first group was penetrated roving by epoxy matrix without surface treatment (labeled “Pure 0 %”), the second group was penetrated roving with surface treatment using technical silica sand (“Pure + sand 0 %”) and then this principle was repeated with Sika filler added into the epoxy resin matrix during the penetration process. Thus penetrated roving by epoxy matrix with filler without surface treatment (“Pure 2 %”) and with surface treatment (“Pure + sand 2 %”). The amount of filler was selected based on the results of previous experiments – tensile test of penetrated single roving with different types of fillers and with different concentrations. Tensile test is not the subject of this paper.

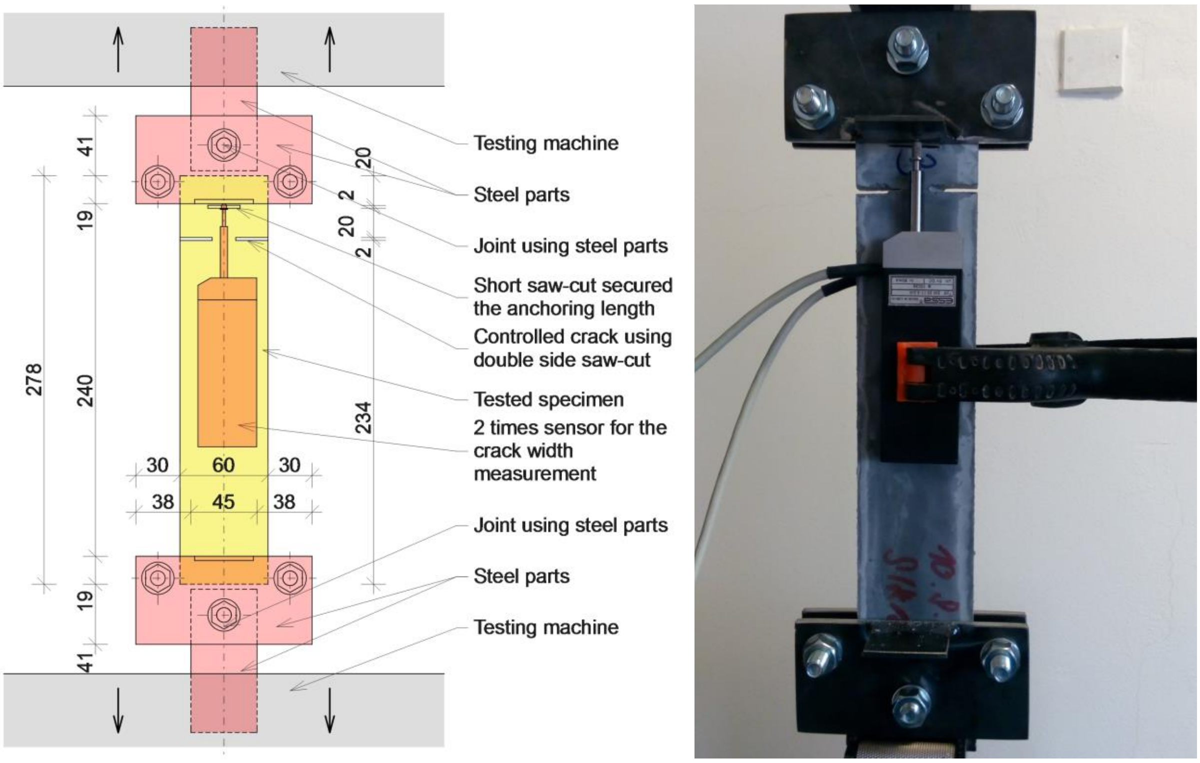

Fig. 1: Specimen dimensions and testing set-up presented at the colored scheme with descriptions and picture just before the start of measurement.

The anchoring length approximately 20 mm is secured using transverse very short saw-cut through the penetrated roving just below the steel part for the installation of the sample into the test machine and controlled crack at the required distance from the upper saw-cut. Double-side saw-cut was used for the predetermined breaking point – controlled crack and this point is also the border of unsymmetrical anchoring length. The length approximately 230 mm in the bottom part is certainly sufficient for the anchoring securing.

During the test procedure for determination of bod behavior were measured time, force, crosshead displacement and development of the crack width using two external potentiometers to obtain an accurate values in the axis of specimen. This experiment was also inspired by similar testing procedure according to ACI 440.3R-04 standard about the test methods for fiber-reinforced polymers (FRP) for reinforcing or strengthening concrete structures. The speed of loading was 2.0 mm/min according to prescribed tensile stress increasing 2.0 MPa/s in mentioned standard. Results are presented in Figure 2 in the form of two graphs. Stress in the first graph was calculated to the cross-sectional area of roving according to technical data sheet without the influence of epoxy matrix. Therefore the maximum theoretical tensile strength is 1.700 MPa but for no specimen was damaged the reinforcement as shown in Fig. 2 and Fig. 3. The HPC was always damaged due to its small cross-sectional area and transverse stresses initiation due to the location of the saw-cuts.

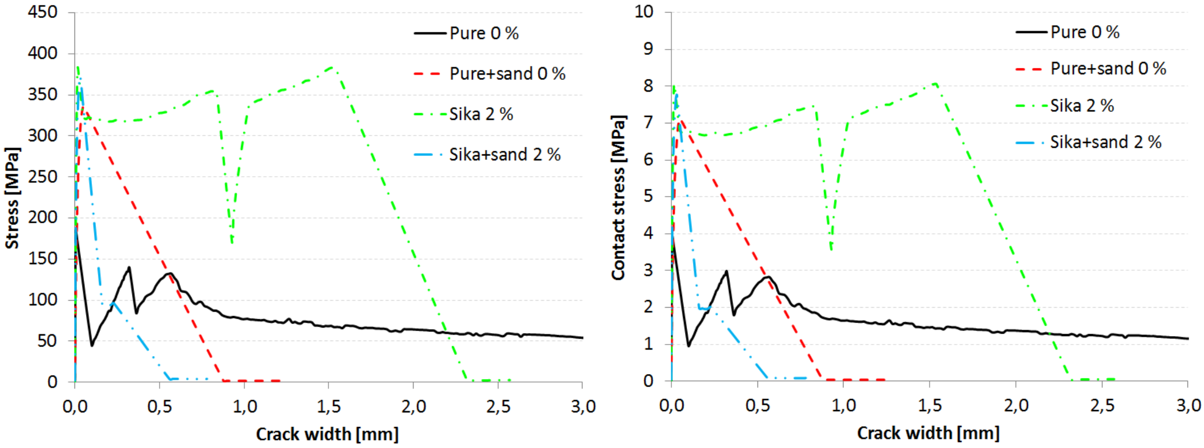

Fig. 2: Tensile stress in composite reinforcement and contact stress between composite reinforcement and cement matrix depending on the crack width development.

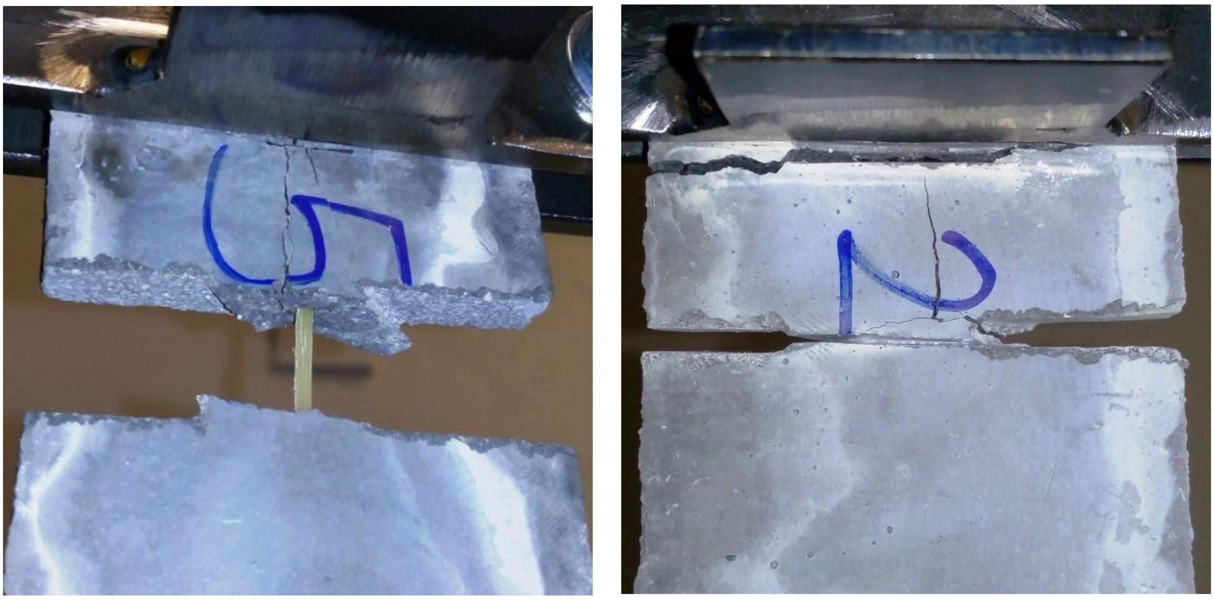

Fig. 3: The difference between specimens with and without surface treatments, pictures were made immediately after the test was interrupted due to the sample breaking.

In Figure 3 is presented the difference between specimens with and without surface treatments. The left part of Figure 3 for the sample without surface treatment shows gradual pulling-out of reinforcement from the HPC sample. Area in the contact with concrete is reduced during pulling-out and therefore there is a gradual decrease of force. Or as in the case presented in Figure 3 in the left is damaged the concrete specimen due to the irregular cross-section shape and concentration of radial stress around this point. This results in the longitudinal crack formation in the place of composite reinforcement. The right part of Figure 3 presented the specimen with surface treatment. It is seen the localization of controlled crack. In a short time after its formation and minimal crack opening occurred violation of concrete in longitudinal direction of reinforcement without expressive slipping of composite reinforcement and without violation of composite reinforcement.

Conclusions

It is known filler addition and surface treatment should have positive influence on the mechanical properties. Graphs in Fig. 2 present the behavior just after the controlled crack initiation. In the case of pure specimen without any treatment there was a gradual pulling out with low bond. Specimen with filler had similar behavior with much better bond behavior until the damage of HPC. Both groups with the surface treatments have similar great results. There was almost no crack opening after the crack initiation. In the moment of critical stress in HPC part specimen were damaged and the stresses dropped to zero. This effect was enhanced by the shape of specimen with its short saw-cut because it led to the transverse tensile stresses initiation. Based on the results this method of the pull-out test should be modified for penetrated roving with surface treatments or filler addition into the epoxy resin matrix. Bigger cross-sectional area of concrete outside of controlled crack is required or concrete for the pull out test should be reinforced. Also short saw-cut for securing of anchoring length should be as short as possible or made by driller because of the transverse tensile stresses initiation which reduce the resistance of the concrete profile.

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