FIBRE-REINFORCED ADHESIVES – ANALYSIS OF COMPOSITE EFFECTS

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Introduction

Adhesives, in their conventional form, are used mainly as glue, in order to connect two construction units of different or same kind firmly bonded with each other. A use of adhesives as volumetric carrying elements is not so far well-known due to the comparatively small course tensile strength. In an AiF[1] promoted research project of the Bauhaus-Universität Weimar fibre-reinforced adhesives are manufactured and their characteristics are examined.

For the suitability test of the different adhesive and fibre systems a large number of available materials are analysed. The verification of the composite load carrying behaviour takes place experimentally and numerically in different micro and macro models. Excellent material stiffness and strength of the adhesive fibre composite material can be laboratory-confirmed.

Additionally to the known good physical properties of the injection moulding materials, the fibre-reinforced adhesives show a high adhesive capacity. Thus offers a wide field of possible application. This kind of fibre-reinforced adhesive is used for the production of windows and as reinforcement in concrete structures.
On adhesive fibre composite material based connections or reinforcements causes torsion-resistant construction units, which possess a much better usability compared with conventionally manufactured construction units.

Basics of Composite materials

Based on numerical analyses the influence of model and material parameters are analysed for the load deflection behaviour of the connections. A detailed analysis on the micro level (fibre matrix) is theoretically very complex. The most common carbon fibres have a filament diameter of D = 7 µm.
Practical investigations in these dimensions require a high experimental effort. Numeric investigations in the micro dimension show a high non-linearity in the force transmission between fibre and adhesive. Caused by the substantially smaller elastic module of the adhesive compared to the fibre the force transmission is concentrated in the start and end regions of the connection between fibre and adhesive (see illustration 1).

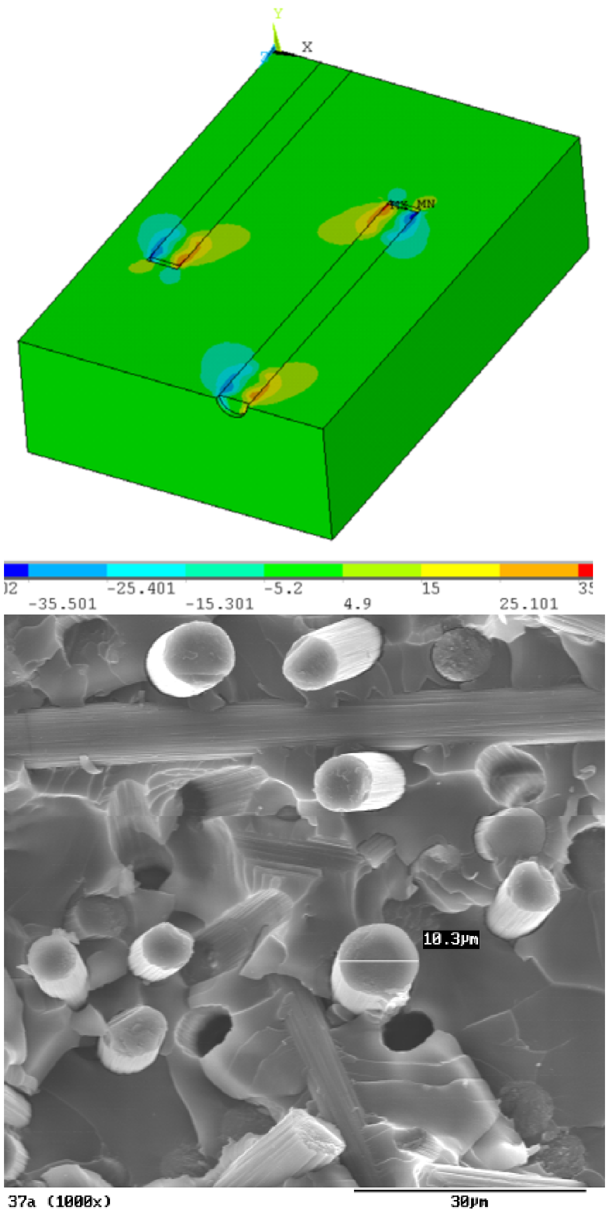

Illustration 1: top: numerical analysis of the force transmission between adhesive and fibre material on a tensile load situation; Evaluation of the shear stresses τ in [N/mm ²]; bottom: Failure picture after a tensile test with epoxy resin adhesive with uncoated carbon fibres

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Fibres with medium length (5 mm $\leq l \leq$ 10 mm) and long fibres (l > 10 mm) do not have any advantages compared to short cut fibres relating to the strength of the adhesive fibre composite material. For the selection of the fibre length other factors are important such as wettability of the fibres, mixture characteristics and formation of air bubbles.

By using of REM, the analyses of the surfaces of fracture can be done very detailed. According to this, an optimal composite load carrying behaviour is only possible by coating of the carbon fibres with silane (see illustration 1 above, the surface of fracture of an adhesive fibre composite material with uncoated carbon fibres).

According to different FE-simulations in the micro level a restriction takes place on the Meso and/or macro level (averaged material properties) for the further work in the numeric simulations.

Experimental and numerical approach

In order to receive fundamental statements about the behaviour of the adhesive fibre composite material, it was necessary to perform three different experimental tests.

The tensile test with tensile bars according to the German code DIN EN ISO 527-4 allows the analysis of Young's modulus, tensile strength and breaking behaviour (see illustration 2).

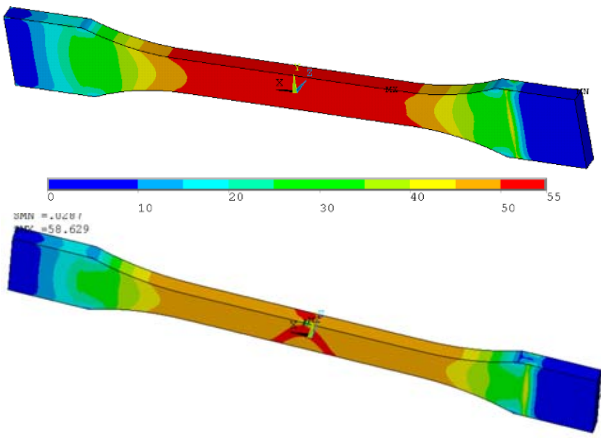

Illustration 2: numerical analysis of a tensile test with a tensile bar according to German code DIN EN ISO 527-4 top: Equivalent stresses σ in [N/mm ^{2}] during the tensile test before the first initial crack; bottom: Equivalent stresses σ in [N/mm ^{2}] after the first initial crack occurred

Shear cutting tests for the analysis of the adhesive properties of the composite material in connection with aluminium are realised with a hollow section made of aluminium, which is filled with the composite material. This experimental configuration permits the determination of the effects of shrinkage behaviour during the curing process in interaction with the temperature strain behaviour of the different material combinations on the adhesion connection.

Conclusion

The realised investigations show, that there are different, economic and technically interesting fields of application for the adhesive fibre composite material. Further analyses are necessary to improve the material systems, especially in the field of durability and fatigue.

The concrete surface coating with adhesive fibre composite material represents a new possibility for substitution of conventional reinforced concrete. The adhesive fibre composite material has the function of a surface reinforcement. The main advantage compared to reinforcement made of steel bars is a strongly reduced crack width also in zones of concentrated loads. The load-carrying capacity of the concrete construction unit can be influenced with the thickness of the composite material layer.

For an exact adjustment of a constant adhesive fibre composite material layer thickness in the production process the development of a volumetric dosage system is necessary. The adhesive fibre composite material has a high viscosity before the hardening process starts. Thus makes it possible to perform the coating process also in overhead positions. The coating process is in general performed after the hardening process of the concrete is completely finished. So it is possible to use this method also in the field of reconstruction and revitalisation of existing buildings.

References

[1] Research report AIF/PROINNO: „NEUARTIGE KLEBTECHNIKEN FÜR ELEMENTE IM FASSADENBAU“ Research report of the Bauhaus-Universität Weimar with Rudolstädter Systembau GmbH and innovative Klebtechnik Zimmermann; June 2008