

Available online at www.sciencedirect.com**SciVerse ScienceDirect**

Procedia Engineering 40 (2012) 38 – 43

**Procedia
Engineering**www.elsevier.com/locate/procedia

Steel Structures and Bridges 2012

Bond strength of chemical anchor in high-strength concrete

J. Barnat^{a,*}, M. Bajer^a and M. Vyhnánková^b^a*Department of Metal and Timber Structures, Faculty of Civil Engineering, Brno University of Technology, Veveří 331/95, Brno 602 00, Czech Republic*^b*Lena Chemical s.r.o. Uničovská 68 –Šternberk, 785 01, The Czech Republic*

Abstract

This paper summarizes the results of experimental and numerical research focused on determination of the behavior and bond strength limits of what are currently the most widespread industrial glues used for anchor bonding. The goal of this research is to find the limits of the effective use of such glue types in high performance concrete, and also to verify the most commonly used design methods for bonded anchors. The progress and configuration of the experiments are described. The goal of this research is to find the limits of effective use of these glue types in high performance concrete and also verification of mostly used design methods. The article is closely focused on bond strength experiments using high strength concrete up to class C50/60 or higher.

© 2012 Published by Elsevier Ltd. Selection and review under responsibility of University of Žilina, FCE, Slovakia.
Open access under [CC BY-NC-ND license](https://creativecommons.org/licenses/by-nc-nd/4.0/).

Keywords: bonded anchor, load bearing capacity, bond strength, experiment, tensile load, high performance concrete

1. Introduction

The presented research is focused on issues of bond quality and the combined concrete-bond failure of bonded anchors loaded by tensile force. It details an experimental analysis of the glue-concrete interface and the effect of its parameters on anchor behavior. Usually, in most design approaches the ultimate tensile load-bearing capacity is based on the simplified assumption of separated failure modes. The final design value is covered by a relatively high safety factor. This assumption is also used in certification regulations for post-installed anchors in concrete e.g. the relevant ETAG [1]. It is obvious that this failure is influenced by the characteristics of both the concrete and the glue. Fully separated failure modes occur only theoretically [2]. A real-life failure will only appear similar to a full concrete failure when low strength concrete is used. Also, a real-life failure will only appear similar to a full bond failure when high strength concrete is combined with common industrial glue.

* Tel.: +420541 147305; fax: +420541 147305.
E-mail address: barnat.j@fce.vutbr.cz

Nomenclature

$N_{u,k}$	characteristic tensile anchor resistance
h_{ef}	effective anchorage length [mm]
$f_{cc,150,k}$	characteristic compressive concrete strength assessed for 150 mm cubes [MPa]
τ_{Rk}	characteristic bond strength
d_0	diameter of the drilled hole

1.1. Combined Concrete-glue failure mode

The following relation (1) for the tensile resistance of an anchor experiencing the combined concrete-bond failure mode has been published in [2].

$$N_{u,k} = \pi \cdot \tau_{Rk} \cdot d_o \cdot h_{ef} \cdot 0.74 \left(1 - e^{-\frac{1.5 f_{cc,150,k}}{\tau_{Rk}}} \right) \tag{1}$$

Fig. 2 shows the results obtained by equation (1) for different bond strength values in relation to concrete strength. According to previous experimental results for the bonds provided by currently used glues [3], such bond strengths range from 15 to 20 MPa. This bond strength value, together with the standard anchorage length, which is about nine times the anchor diameter, ensures the effective utilization of materials with a concrete class of up to C40/50 and a steel bolt quality of 8.8.

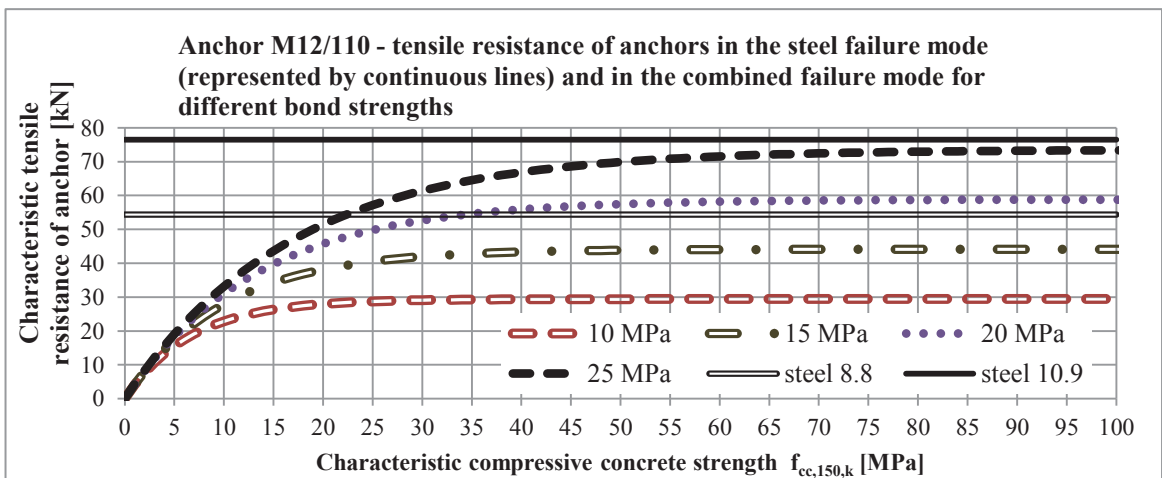


Fig. 1. Pull out resistance of anchor according to (1)

2. Experiments-Bond strength limits

Tension resistance of bonded anchor can be increased together with larger anchoring length. However due to geometric conditions this solution is not always possible. This can be a problem of modern structures using high performance materials. The experiments described in this paper are focused on verification of bonded anchor tension resistance limits determined by bond strength provided by the glue. Bond strength is an overall parameter used for description of connection quality between the steel anchor and concrete. The main principle of the bond quality test used (as depicted in the schematic diagram in fig.1d) is to restrict bond failure to the anchor only. Load is applied to the anchor bolt by the loading mechanism which is itself supported by the concrete in the immediate vicinity of the installed anchor. Bond strength is defined as shear stresses on one of the contact interfaces. It can be evaluated on the interface between steel and glue, as it is in ETAG or on the interface between glue and concrete, which is more suitable for description of combined concrete-bond failure mode. The experiment sample is shown in fig. 2a) and the scheme of experiment configuration is in fig. 2d). Fig. 2b) and c) are showing similar configuration of experiment with use of steel specimen instead of concrete. This configuration was used for determination of shear strength of hardened glue not influenced by concrete strength. Steel specimens were manufactured with internal female thread to ensure fine mechanical connection between steel and glue. The thickness of glue layer was set to 1 mm as it is usual in common bonded anchors systems.

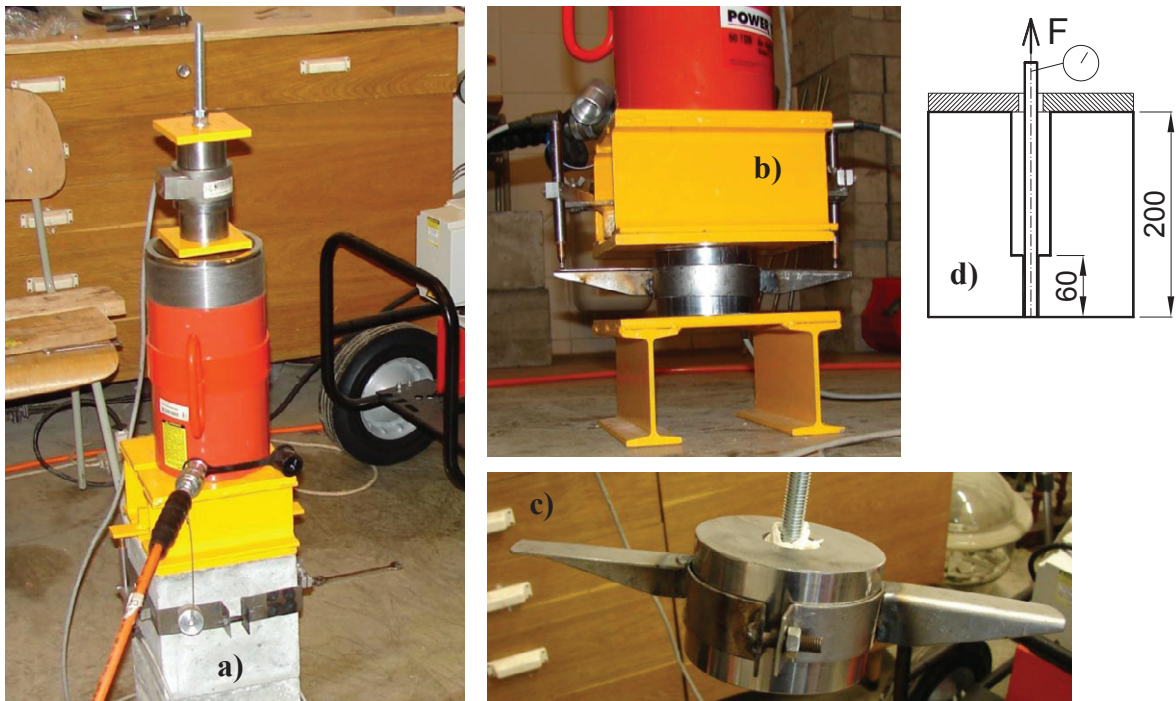


Fig. 2. a) experiment configuration with concrete specimen, b) experiment configuration with steel specimen, c) steel specimen with female thread d) scheme of bond quality experiment

The ETAG [1] covers anchoring in concrete up to class C50/60. As it is shown in fig.1 anchor in concrete of this strength together with use of anchor made from steel 10.9 is also limited by bond strength reaching the value of 25 MPa. This is according to previously made experiments also limit of commonly widespread glues based on epoxy resin. Three mixtures of concrete were used in described experiments. The results of laboratory concrete strength tests proved that the mean values of the concrete mixtures were 71.8 MPa, 82.1 MPa and 80.7 MPa. 6 cubes were tested for each mixture. All three mixtures fulfill the criteria for C55/67 concrete. The characteristic values evaluated according to the relevant Eurocode were 67.9, 76.2 and 72.0 MPa, respectively.

One of the highest quality available glues based on epoxy resin (HILTI HIT-RE500) was tested, together with three experimental epoxy glues, EXP2012/1, EXP2012/2, EXP2012/3 produced by Lena Chemical, s.r.o.

All concrete specimens were tempered at 15°C-20 °C for several days. Also anchor installation and glue hardening process was accomplished at the same laboratory temperature. Hardening time, for all specimens was set to 72 hours to ensure full mechanic parameters of hardened glue.

All glues were tested on three specimens from each concrete mixture. Next two graphs (fig. 3a – fig. 3b) show the working diagrams obtained by experiments with glue EXP2012/3. Graph on fig. 3b shows results for all concrete mixtures together. Peak values of bond strength of glues (determined as average value from all tests) are shown in Fig. 4a.

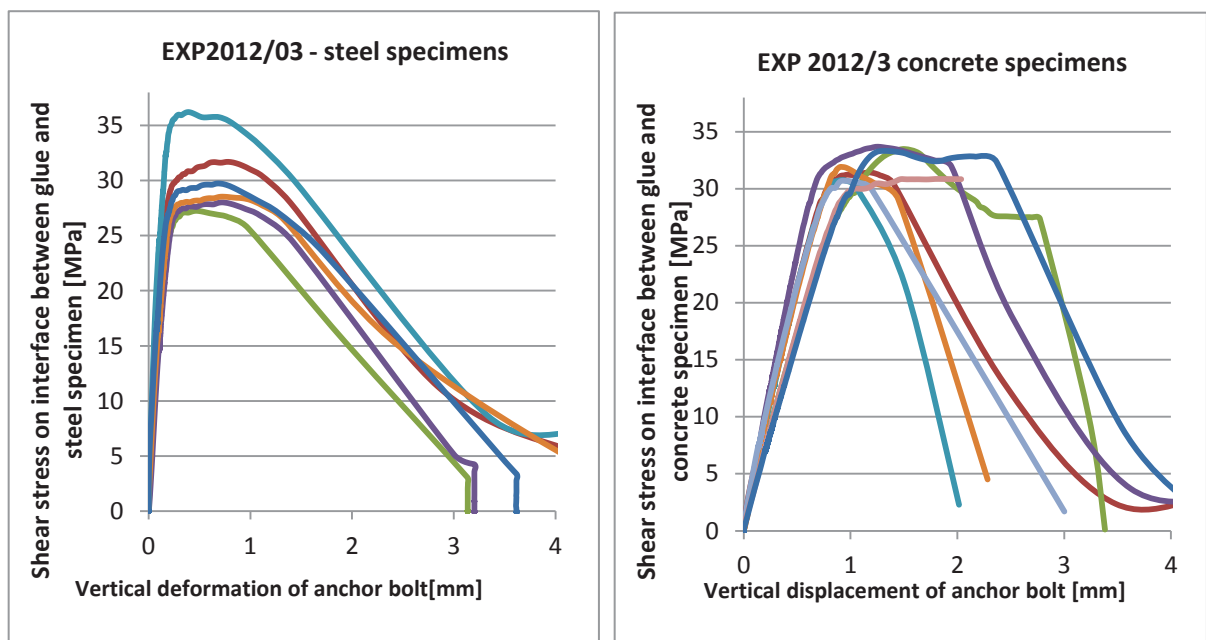


Fig. 3. a) Results of EXP2012/3 in steel specimens b) Results of EXP2012/3 in concrete specimens

3. Conclusions

Fig. 4b shows three representative specimen of EXP2012/3 after failure occurred during the tests. This failure is possible to designate as glue failure. Glue is disrupted mainly at the interface between steel bolt and

glue. Stresses shown in fig. 3a and also in fig. 3b are both evaluated for interface between glue and concrete. The reason of small difference between the bonds strength determined from concrete and steel specimen is the small number of realized tests. In principle value obtained from steel specimen there the bond strength is not influenced by concrete characteristics should be equal or higher to value from any concrete specimen.

Shear strength of glue should be determined from failure on interface between steel and glue. For experimental glue EXP2012/3 the mean value of this strength is 35.3 MPa. The results presented in fig 4a show that the bond strength of the tested glues was not dependent on concrete strength. Analysis of the results presented in this paper has confirmed that the characteristics of glue are the limiting factor for chemical anchoring in high performance concrete.

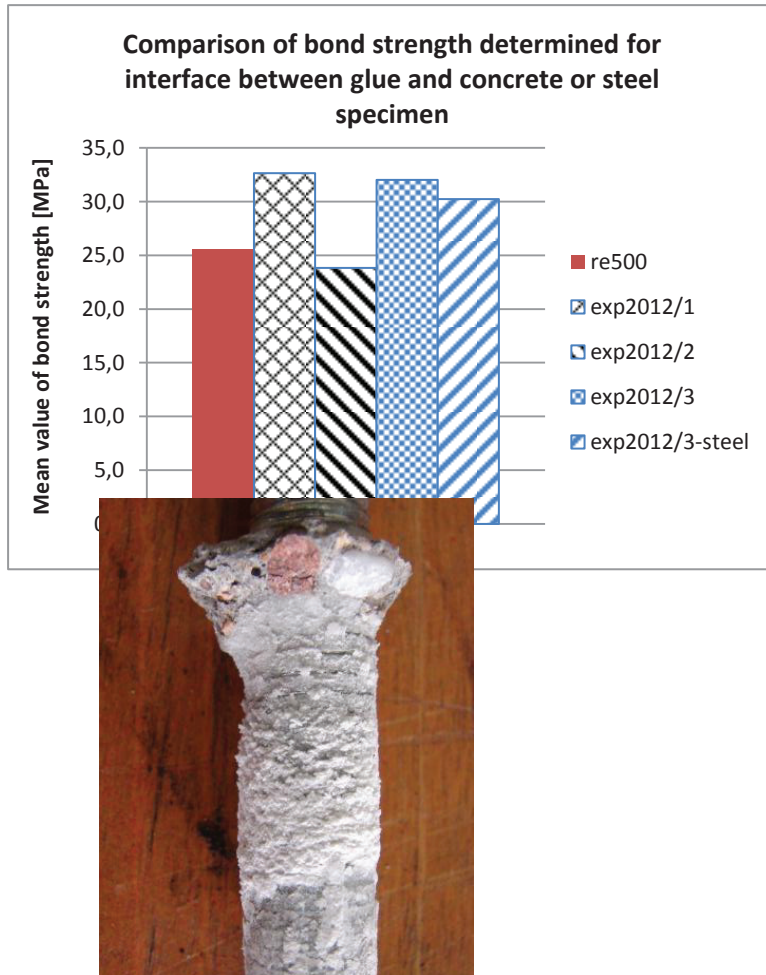


Fig. 4 a) Bond strength for all tested specimens b) Sample of EXP2012/3 after the failure

Therefore, the goal for further research is to modify the composition of glues to achieve improved mechanical characteristics suitable for use in high performance concrete.

Acknowledgements

This paper was elaborated within the framework of research project GACzR P104/11/P737 and with the financial support of Ministry of Industry and Trade of the Czech Republic through the project TIP č. FR-TI4/332

References

- [1] ETAG 001 Anchoring design methods, EOTA-European Organisation for Technical Approvals, Avenue des Arts 40, Kunstlaan, 1040 Brussels, 2006
- [2] Bajer. M., Barnat.J.: The glue–concrete interface of bonded anchors, *Construction and Building Materials* 34 (2012) p.267–274, 2012, ISSN 0950-0618
- [3] Barnat. J.: Behaviour analysis of steel bonded anchors, Ph.D. Thesis, pp. 16-18, ISSN 1213-4198, ISBN 978-80-214-4162-0 , Brno University of Technology, Faculty of Civil Engineering, 2010