TECHNISCHE UNIVERSITÄT MÜNCHEN

cbm

Centrum Baustoffe und Materialprüfung

TUM · Lehrstuhl für Baustoffkunde und Werkstoffprüfung
Baumbachstraße 7 · D-81245 München

Bundesamt für Bauwesen und Raumordnung/Zukunft Bau

Dr.-Ing. M. Brüggemann

Deichmanns Aue 31-37

53179 Bonn

Lehrstuhl für Baustoffkunde und Werkstoffprüfung
Universitäts- Professor
Dr.-Ing. Ch. Gehlen

Baumbachstraße 7
D-81245 München

Tel. +49 (0) 89-289-2 70 61
Fax +49 (0) 89-289-2 70 64
cbm@cbm.bv.tum.de

AG 3 Stahl und Korrosion

München, den 03.09.10

SUMMARY

Nr.: 30-F-0016

Research work: **„Investigations about temperature behaviour of glued rebar connections“**

This research project was funded by the research sponsorship „Zukunft Bau“ of The Federal Office for Building and Regional Planning (BBR).

File reference: Z 6 – 10.08.18.7-07.24 / II 2 – F20-07-4

The authors of this report are responsible for the contents.

Project leader: Dr.-Ing. Andreas Volkwein

Consultant: Dipl.-Ing. Marc Zintel

1 Aim of the research

The mechanical connecting of reinforcement bars (rebars) using mechanical connecting elements is designated in Germany according to DIN 1045 and is also commonly used in international practice. Techniques available at the moment are for example, the press on of a steel-sleeve or the installation of a screw thread at the ends of the rebars and connecting it to a thread sleeve or screwing sharp bolts across into the sleeve to fixate the ends of the reinforcing concrete bars.

Due to some adverse characteristics of such connections (especially cracks in concrete in consequence of slip as well as fast fatigue under dynamic stress) this research follows the idea of gluing rebars into inside profiled steel-sleeves with a synthetic fastly hardening resin which is available today on the market. Hereby it was expected to have favourable characteristics for the two named disadvantages. It was aimed to carry the ultimate tensile strength of rebars.

Older research work has been carried out by using cement mortar as well as synthetic resin mortar as glue. But until today these first approaches did not gain acceptance.

Regarding to the load-transmission such a bond to rebars is very similar to shear connectors as well as the authorized gluing of rebars into drilled holes in the concrete. For that an extensive amount of literature is available. A series of knowledge from these areas can be transferred to the load bearing capacity between the sleeve and the rebars. Beside the common proofs of a sufficient carrying capacity (static, dynamic) it was essential to detect accurately the behaviour under temperature, which includes the creep as well as the sustained loading strength. Effects under temperature also include the behaviour under fire impact. According to this an optimisation of the mortar may be necessary. Therefore the aim was to prove the favourable characteristics and advantages of such a connection and to find possible unfavourable characteristics and if necessary to achieve improvements for implementations to practice. It also means if necessary to develop a basis for standards and guidelines.

2 Execution of the research

For experimental research of such a type of connection, a steel-sleeve prototype with an inside thread developed by the company Pfeifer was available. The annular gap between sleeve and rebar was planned to be press-fitted with an authorized reaction resin mortar (a). In figure 1 the construction of the used glued rebar connection is shown. Examples of the sleeve dimensions are for the rebar diameter 8 mm: $D_{external}$ = 18 mm, length = 210 mm and for 28 mm: $D_{external}$ = 51 mm, length = 450 mm. The clear opening of the annular gap varied between 1 and 2 mm.

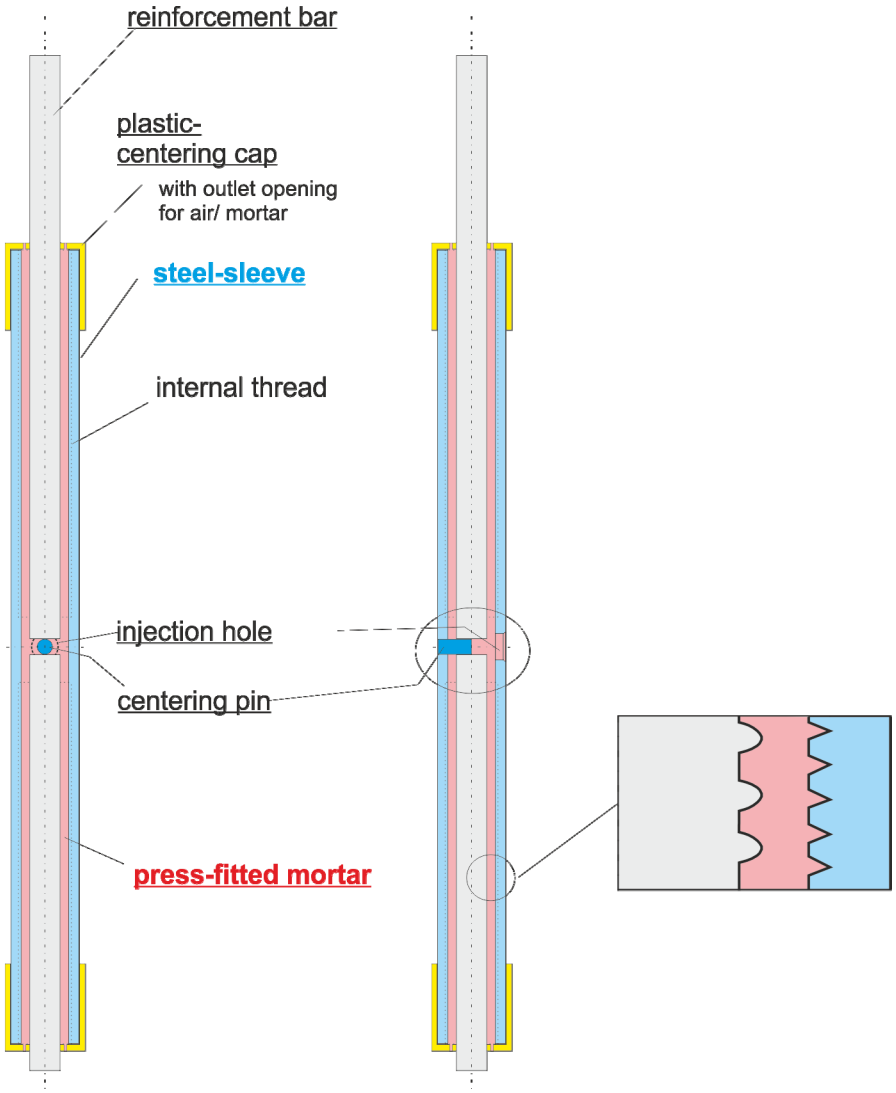

Figure 1: Schematic diagram of the used glued rebar connection (Prototype developed by company Pfeifer, Memmingen)

Initially the reaction resin mortar (a), authorized for anchors, was used for the press-fitting. With that the slip and the short term tensile strength was determined at room temperature as well as at temperatures above (up to 80°C). In dynamic fatigue tests the Wöhler Line was also determined. Further long-term tests for creep were performed. The creep rupture strength which was aimed to determine too was not possible to verify since no cracks have been observed till now. In essence it was established that the used mortar is not appropriate according to the slip in the short term tensile test and to the creep. The dynamic fatigue test showed the expected behaviour that means no negative impact in respect to unconnected rebars.

Regarding the established very high ductility of this mortar, especially under temperature impact developments of more suitable mortars have been promoted. To fill the gap between the rebar and the steel sleeve the use of steel shot combined with press-fitting of the remaining cavities with synthetic resin appeared to be promising. This technique is known in other parts of the building industries as “prepact-procedure”. By this the necessary grain-to-grain-contact can be established and the task of the polymer is merely to keep the steel shot in place. Even

without polymer it has been shown that the full tensile strength is reached. However the filling of the annular gap with steel shot was only done in the laboratory. In this case practical solutions still have to be developed.

In co-operation with the producer of the reaction resin mortar a third mortar was developed with coarse quartz aggregate, which is called “injection mortar (b3)“. In fact this mortar delivered a more favourable behaviour, but compared to the steel shot the results were still not satisfying, which is shown in figure 2.

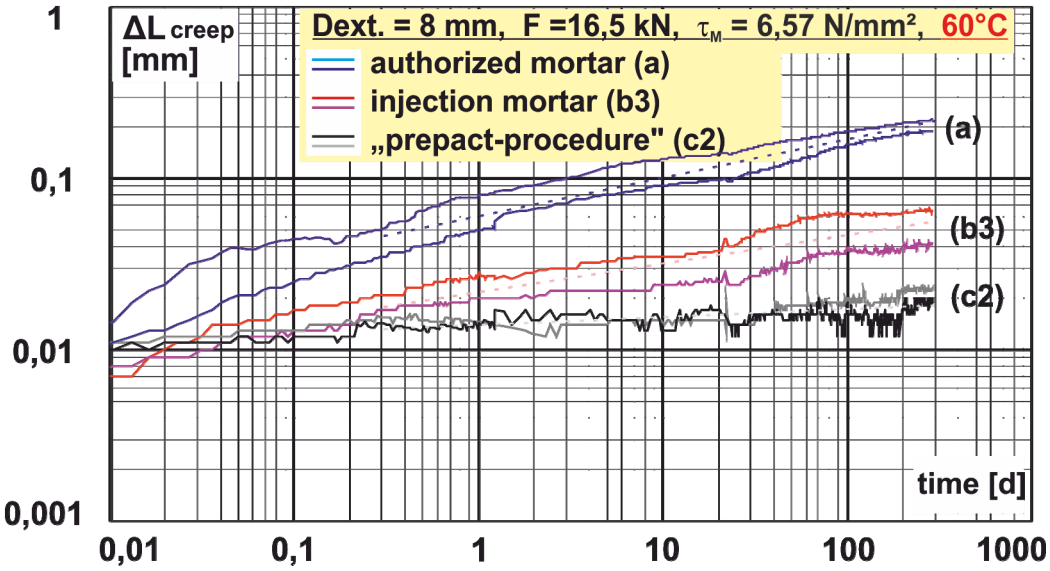

Figure 2: Creep at a rebar diameter 8 mm at a tensile stress of 328 N/mm²

The analysis of the creep test results showed that the approximation approach of Norton (1929)/ Baily (1935) is quite suitable. Among others a light dependency of the exponent has to be added according to temperature conditions.

With connections produced with press-fitted steel shot two pairs of concrete beams were constructed and tested in two fire tests until rupture at the MPA of TU Braunschweig. The beams were designed for F60 respectively F90. The failure of the glued connection in the midspan occurred at temperatures inside the connection between 400 and 500°C. In the shear area no failure was observed. The fire resistance of the two different concrete covers was slightly under F60 respectively a bit more.

The connections which were heated too but did not break in the fire test (not situated in the midspan) were used to test the tensile strength. The decrease of strength surprisingly appeared to be only between 0 and 19%.

3 Summary and prospect

As a general conclusion: The realisation of a glued rebar connection in combination with authorized reaction resin mortars, which are commonly used for anchors, is infeasible. The main reason is the tensile creep deformation especially under high temperatures (e.g. already when subjected to the sun). This would cause severe cracking of the concrete.

Perhaps modifications could be achieved by for example increasing the sleeve lengths and at the same time tapering the sleeve ends to spread the crack formation. Nevertheless a higher fire resistance appears not to be achievable.

As the investigations showed it is most important how proper and save the grain to grain contact inside the mortar can be activated. In this case the grains should not yield, e.g. in case of too low strength. The steel shot which was used in the investigation seems to be the right way of a solution. Perhaps it may be an advantage if the shape of the steel shot is not spherical, what should be still investigated. The resin itself must only be used for the fixation and should not act as a lubricant between the grains. This is very important under fire conditions. Also more promising would be to use inorganic glue/mortar, if they harden in an adequate rate.

Producing a grain-to-grain-packing in the annular gab under site conditions may be a big problem. Just in that connection further developments have to apply here. If there exists a practical method then the glued rebar connection would have chances in the future.

From the investigations also valuable stimulations for other areas, especially for the anchorage of rebars or anchors in concrete can be deduced.

Acknowledgement:

The company Pfeifer Seil und Hebetechnik GmbH, 87700 Memmingen supported the research with essential materials like resin, reaction resin mortar and steel-sleeves and funded some of the costs for the fire tests. In this case special thanks go to the company.