Institut für Baustoffe, Massivbau und Brandschutz
Materialprüfanstalt für das Bauwesen
TU BRAUNSCHWEIG

Expert report

- Translation -

Document number:	(3526/607/14) - CM of 17. December 2014
Client:	RIPPLE CONSTRUCTION PRODUCTS PVT LTD+ Above SBI Bank, Balkampet Main Road S R Nagar 500 038 Hyderabad INDIA
Order date:	28/04/2014
Order Ref. No.:	Mr Strater
Order received:	28/04/2014
Subject:	Ripple Injektionssystem V-Fix used for post-installed rebar anchors to be tested and assessed for its behaviour at high temperatures
Test basis:	Given in section 1
Samples received:	-
Sampling:	The material testing laboratory has received no information about official sampling of the supplied material.
Sample marking:	None
Date of test:	-
Valid until:	19. October 2019

This expert report consists of 14 pages (incl. cover sheet) and 10 annexes.

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1 Background and commission

With their order of 28/04/2014, RIPPLE CONSTRUCTION PRODUCTS PVT LTD+ commissioned MPA Braunschweig to prepare a fire-engineering design concept for BSt 500S reinforcing steel rebar connections, Ø 8 mm to Ø 25 mm diameter, using the Ripple Injektionssystem V-Fix in reinforced-concrete (RC) slabs or wall sections exposed to fire on one side.

The fire-engineering design concept for the Ripple Injektionssystem V-Fix in connection with RC members exposed on one side to a time-temperature curve fire according to ISO 834 is based on tests made to examine the Ripple Injektionssystem V-Fix with respect to its high-temperature behaviour and its thermomechanical properties:

Also used as a basis were:

[1] „Beton-Brandschutz-Handbuch", Prof. Dr.-Ing. Dr.-Ing. E.h. K. Kordina und Dr.-Ing. C. Meyer-Ottens, Ausgabe 1981, Hochtemperaturverhalten von Stahbetonbauteilen bei einer einseitigen Brandbeanspruchung nach der Einheitstemperaturzeitkurve gemäß ISO 834 bzw. DIN 4102-2 : 1977-09, „Brandverhalten von Baustoffen und Bauteilen. Bauteile, Begriffe, Anforderungen und Prüfungen",

[2] DIN EN 1992 Teil 1-1, „Eurocode 2 : Planung von Stahlbeton- und Spannbetontragwerken; Teil 1 : Grundlagen und Anwendungsregeln für den Hochbau",

[3] DIN 1045 : 2001-07, „Tragwerke aus Beton, Stahlbeton und Spannbeton",

[4] Data sheets provided by the client for the Ripple Injektionssystem V-Fix.

This document is a transfer of Expert Report No. (3371/436/09)-CM dated 07-01-2009 (english translation, the german version of Expert Report No. (3371/436/09)-CM dated 07-1-2009 is the only legally binding text).

2 Description of systems tested

The Ripple Injektionssystem V-Fix tested is an expansion pressure-free anchoring system primarily exposed to static loads in normal-weight concrete with quartzitic aggregate.

The Ripple Injektionssystem V-Fix is an anchoring system which makes use of the bond between the steel, the two-component injection mortar and the concrete. The Ripple Injektionssystem V-Fix consists of a two-component injection mortar (Venylester reaction resins, styrolfree) compounded in two-chamber cartridges, which is forced into the borehole with an applicator through a replaceable static nozzle. The Henkel injection mortar is a binding-agent system, consisting of a resin hardener (components: Methacrylat and inorganic filler) and a hardener (components: Dibenzoylperoxid and inorganic filler). Steel grade BSt 500S (DIN 488) rod iron, Ø 8mm to Ø 20mm, was used as reinforcing steel.

Regarding installation and load application, the Ripple Injektionssystem V-Fix will in future be regulated by an allgemeine bauaufsichtliche Zulassung (abZ) respectively a European Technical Approval (ETA) and by data sheets (instructions for installation, safety data sheet) provided by RIPPLE CONSTRUCTION PRODUCTS PVT LTD+.

Additional details concerning the application and the design options available with the Ripple Injektionssystem V-Fix are shown in annexe 3 of this expert report.

The Ripple Injektionssystem V-Fix has to be installed as described in the data sheets of RIPPLE CONSTRUCTION PRODUCTS PVT LTD+, using the tools (hammer drill, drill, applicator and static nozzle, cleaning device) specified in these data sheets. The cleaning of the boreholes take place with 4 x blaze (compressed air), 4 x brush with stee-brush and 4 x blaze (compressed air).

For detailed specification of the Henkel injection mortar, MPA Braunschweig has performed tests to determine the infrared spectrum and also a thermo-gravimetric analysis (TGA). Test results have been filed by MPA Braunschweig.

For further structural details of the reinforcing bars installed in the concrete cylinders, reference is made to annex 2 of this expert report.

3 Test set-up and testing

A total of 27 reinforcing-steel sections, nominal diameter Ø 8mm to Ø 25mm, steel grade BSt 500S, were placed into steel-encased concrete cylinders in connection with the Ripple Injektionssystem V-Fix. They were then subjected to centric tensile loads and examined for their high-temperature behaviour for assessment of their thermomechanical properties and pull-out values, and for preparation of a fire-engineering design concept for installation of rebar anchors.

The tests were performed in an electrically heated servohydraulic high-temperature test aquipment. A borehole (d_0) was drilled into each concrete cylinder in the middle of its base. The size of the borehole corresponded to the placement depth l = 5 x bar diameter (d_s), 7 x bar diameter (d_s) and 10 x bar diameter (d_s) and had a pre-defined borehole diameter, which corresponded to the rod iron diameter plus 2 x annular gap width. The boreholes were then cleaned, and the reinforcing bars were placed with the Ripple Injektionssystem V-Fix. Before placing the reinforcing bars they were provided with temperature measuring elements in such a way that temperatures could be measured in the Ripple Injektionssystem V-Fix at a depth of about 10 mm below the concrete surface and at the bottom end of the reinforcing bars, immediately next to the borehole toe. For centric load application to the BSt 500S reinforcing steel, the pressure cylinder available in the test aquipment was used.

Temperatures inside the test aquipment were measured with temperature sensors as defined in ISO 834 (type K) and increased as required. Any relative displacement between reinforcing bars and concrete surface during the tests was continuously recorded with a measuring device provided outside the furnace.

The tests for determination of the general high-temperature behaviour of RC members as described in Beton-Brandschutz-Handbuch [1] were made in test furnaces, in which the specimen had one side exposed to a fire in compliance with the ISO 834 standard temperature-time curve.

For further structural details of the concrete cylinders mounted in the test aquipment, reference is made to annex 1 of this expert report.

4 Test results

Between week 36, 2008 and week 9, 2009, a total of 27 Ripple Injektionssystem V-Fix were placed into concrete cylinders of concrete grade ≥ C20/25 in connection with BSt 500S reinforcing steel (nominal diameter Ø 8 to Ø 25 mm) and tested for their high-temperature behaviour when subjected to centric tensile loads. This was done to determine the pull-out values and to provide a basis for preparation of a fire-engineering design concept for installation of rebar anchors. Fire testing was made with the specimens having one side exposed to a fire in compliance with the ISO 834 standard temperature-time curve.

On the basis of the results produced for the high-temperature behaviour of the Ripple Injektionssystem V-Fix, the expert report was to be extended to include rebar anchors with nominal diameters Ø 8 to Ø 25 mm.

The test results produced for the Ripple Injektionssystem V-Fixs are listed in Table 4-1 below with the different failure temperatures.

Table 4-1: **test results of the** Ripple Injektionssystem V-Fix **with rebar sections of steel grade BSt 500 S (nominal diameter of 8 mm to 12 mm)**

Test-number	Date of test	Nominal diameter d_s [mm]	Bond stress τ [N/mm²]	Failure temperature T_u [°C]	Failure cause
1.	27.11.08	8	0,72	175	Pull out
2.	08.10.08	8	1,74	146	Pull out
3.	22.10.08	8	3,48	140	Pull out
4.	28.11.08	8	7,19	50	Pull out
5.	09.10.08	10	0,73	146	Pull out
6.	03.12.08	10	1,09	145	Pull out
7.	21.01.09	10	5,33	69	Pull out
8.	18.09.08	12	0,59	248	Pull out
9.	12.09.08	12	1,00	142	Pull out
10.	04.09.08	12	1,96	141	Pull out
11.	24.09.08	12	2,20	146	Pull out
12.	25.09.08	12	3,39	128	Pull out
13.	29.09.08	12	4,33	139	Pull out
14.	22.01.09	12	4,86	113	Pull out
15.	26.09.08	12	5,96	70	Pull out
16.	11.09.08	12	8,04	55	Pull out
17.	19.09.08	12	10,95	40	Pull out
18.	22.01.09	12	14,04	25	Pull out
19.	11.09.08	12	16,27	25	Pull out

Table 4-2: **test results of the** Ripple Injektionssystem V-Fix **with rebar sections of steel grade BSt 500 S (nominal diameter of 14 mm to 25 mm)**

Test-number	Date of test	Nominal diameter d_s [mm]	Bond stress τ [N/mm²]	Failure temperature T_u [°C]	Failure cause
20.	15.10.08	14	0,54	230	Pull out
21.	17.10.08	14	2,68	136	Pull out
22.	30.10.08	16	0,46	251	Pull out
23.	24.10.08	16	6,90	64	Pull out
24.	11.02.09	20	0,51	210	Pull out
25.	06.02.09	20	9,23	43	Pull out
26.	17.04.08	25	0,55	193	Pull out
27.	23.04.08	25	1,11	140	Pull out

5 Fire-engineering design concept for rebar anchors, using the Ripple Injektionssystem V-Fix

5.1 General

Using the test results produced for the high-temperature behaviour of the Ripple Injektionssystem V-Fix specified in section 4 above, a fire-engineering design concept was to be developed for rebar anchors with nominal diameters Ø 8mm to Ø 25 mm used in RC slabs having one side exposed to a fire in compliance with ISO 834 during fire resistance periods of 30 to 180 minutes.

The fire-engineering design concept was to consider the rebar connection versions **OVERLAP JOINT** and **ANCHORING**, a schematic representation of which is included in Fig. 5-3 and Fig. 5-4, respectively.

5.2 Evaluation of test results and design formulation

Since rebar anchor design formulations normally assume that the bond stress is utilized, Fig. 5-1 shows the test results produced for the Ripple Injektionssystem V-Fix in Table 4-1 and in Table 4-2 as function values for the failure temperature and the corresponding critical bond stress $\tau_{crit,T}$. In addition, test results have been used as a basis to determine a design curve below the actual failure values in Fig. 5-1, which remains on the safe side.

test results Chemofast STVK / ALVK 2K

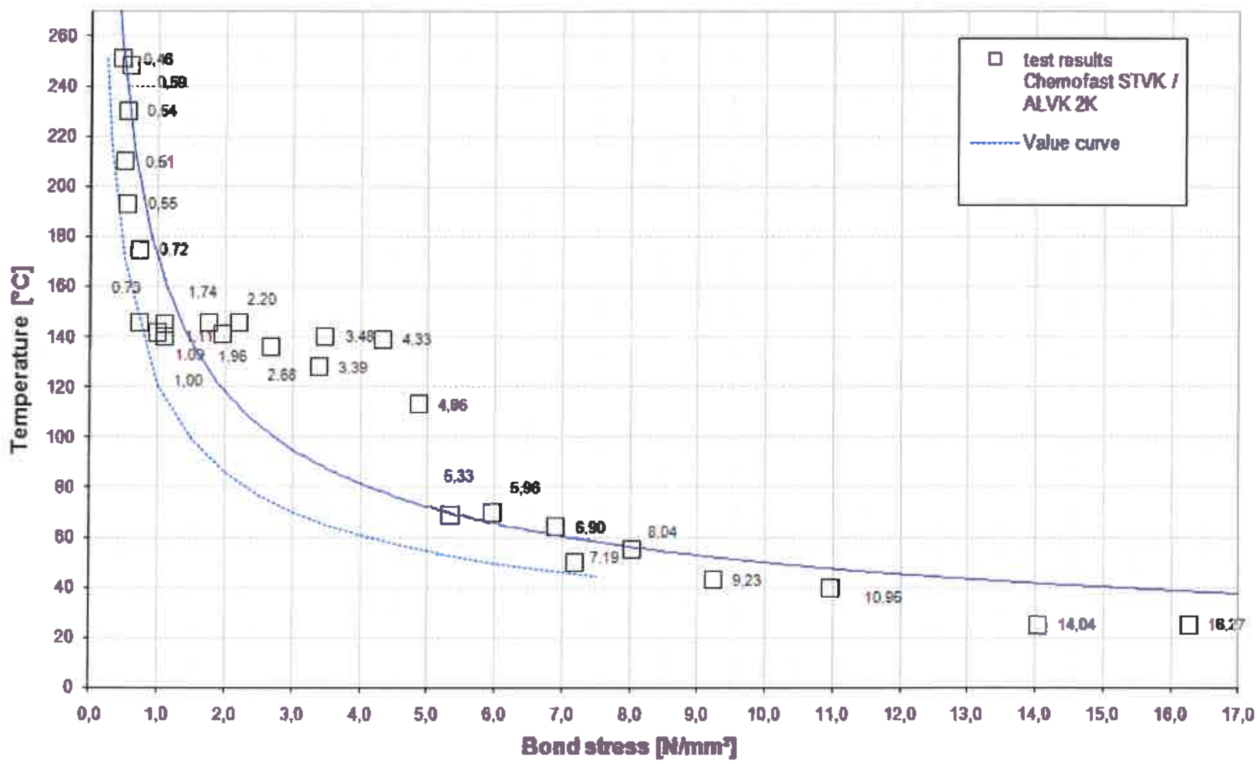

Fig. 5-1: Graphical presentation of test results obtained with the Ripple Injektionssystem V-Fix as well as the design curve as a function of failure temperature and critical, temperature-dependent bond stress $\tau_{crit,T}$

With the heating behaviour of the concrete shown in Fig. 5-2, the design curve in Fig. 5-1, and additional test experience for normal-weight concrete with quartzitic aggregate, the critical temperature-dependent bond stress $\tau_{crit,T}$ can be shown in annex 8 as values on the safe side for the different concrete covers 'c' and for fire-resistance periods 30 to 180 minutes.

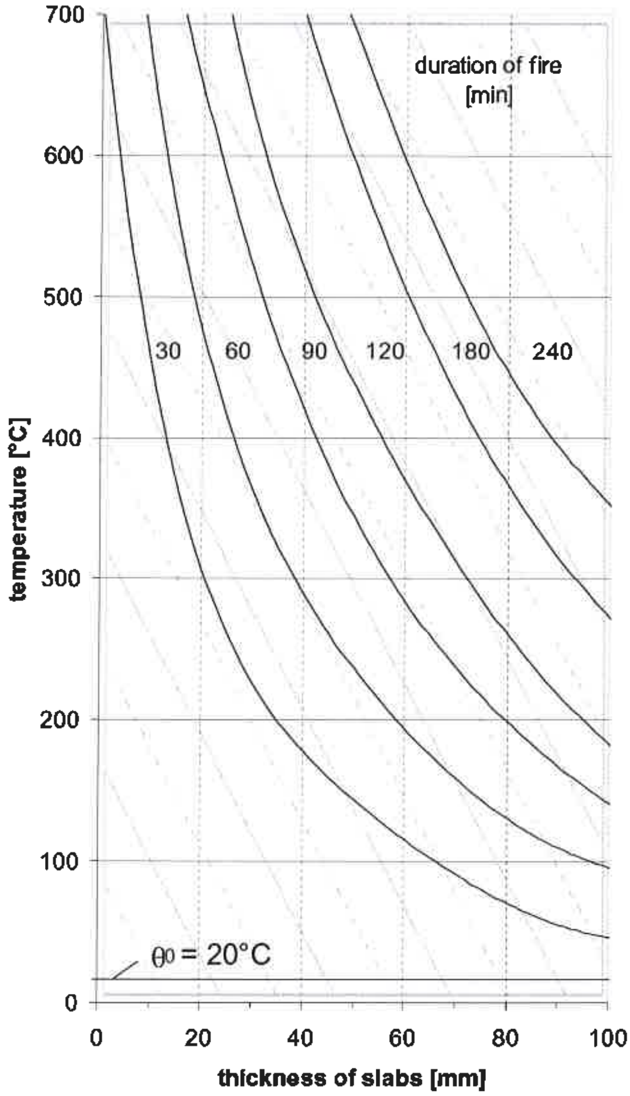

Fig. 5-2: Temperature distribution in slabs and wall sections made from normal concrete with quartzitic aggregates with the specimens having one side exposed to a fire in compliance with the ISO 834 standard temperature-time curve [1]

5.3 Application of the design formulation to the rebar connection version OVERLAP JOINT

Overlap joints exposed to high temperatures have to be numerically calculated on the basis of the following formula (1). Fig. 5-3 shows the principle of the rebar connection version **OVERLAP JOINT**.

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$$F_{s,T} \leq l_v * d_s * \pi * \tau_{crit,T} \quad (1)$$

Where:

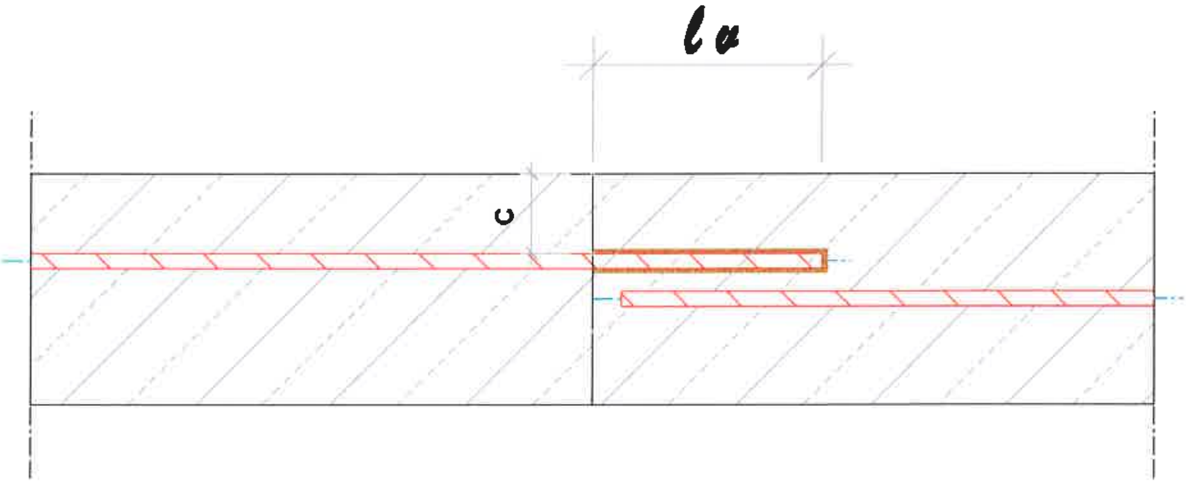
$F_{s,T}$ bar force in fire conditions

l_v overlap length of joint

d_s nominal diameter of reinforcing bar

$\tau_{crit,T}$ critical temperature-dependent bond stress for concrete cover 'c'

Fig. 5-3: Schematic illustration of rebar connection version OVERLAP JOINT



Findings for the critical temperature-dependent bond stress $\tau_{crit,T}$ as a function of concrete cover 'c' and the different required fire resistance times for the rebar connection version **OVERLAP JOINT** are shown in annex 8. It should be noted that the overlap length in a fire must not exceed 80 x d_s.

It is evident from Fig. 5-3 and Fig. 5-4 that with this connection version the entire rebar anchoring region is in parallel with the fire-exposed member surface and hence basically remains within one single temperature range, which is decisive for the load-bearing capacity. From this follows that with this rebar version it would not make sense to extend the placement depth or the overlap length. Since concrete cover 'c' is the only protection against any rise in temperature, an increased concrete cover could provide for full utilization of the loading level, based on the maximum connection bar force ($F_{s,T}$).

An alternative solution instead of increasing the concrete cover can under certain conditions be to quantitatively increase of the joint reinforcement in proportion to the loading level. Protective plaster coating (for example according to DIN 4102-4, section 3.1.6) or other protection systems (for example protection with fireboards) can also meet fire-engineering requirements, provided their fitness for use has been demonstrated. Protection fixtures also have to meet fire-engineering requirements, which has to be demonstrated separately.

5.4 Application of the design formulation to the rebar connection version ANCHORING

The anchoring exposed to high temperatures has to be numerically calculated on the basis of the following formula (2). Fig. 5-4 is schematic representation of the rebar connection version **ANCHORING**.

$$F_{s,T} \leq A_S * \sigma_S \qquad (2)$$

Where:

$F_{s,T}$ bar force exposed to fire

A_S cross-sectional area of rebar

σ_S steel stress at the construction joint that can be introduced with the two-component mortar as a function of rebar placement depth l_v and fire resistance time

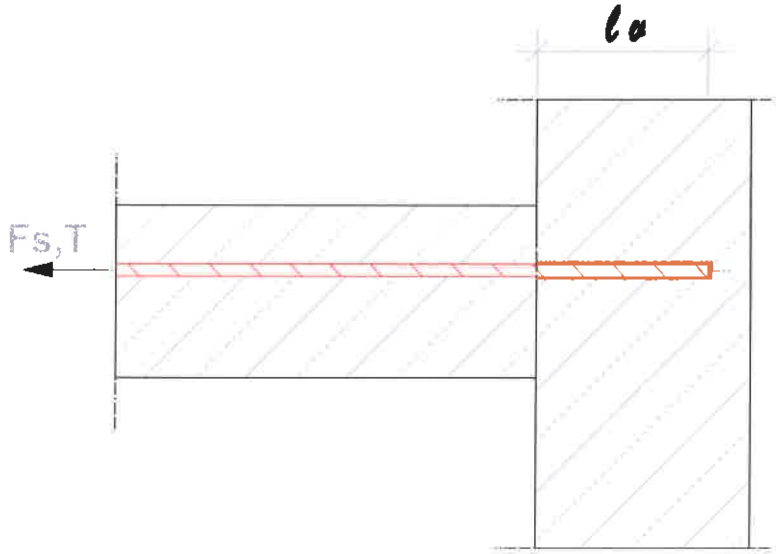


Fig. 5-4: Schematic representation of rebar connection version ANCHORING

For analysis of the rebar connection version **ANCHORING**, the critical temperature-dependent bond strength $\tau_{crit,T}$ is integrated as a function of placement depth l_v of the reinforcement bar and the fire resistance time.

With this connection version, the rebar anchoring region is perpendicular to the fire-exposed member surface and thus crosses different temperature regions. With an increased placement depth l_v, the maximum connection bar force ($F_{s,T}$) can thus be fully utilized with the rebar connection version **ANCHORING**. An alternative would be to quantitatively increase the through-reinforcement for a given fire resistance time. Another possibility is to provide equivalent concrete covers with protection systems, as detailed in section 5.3 above.

This type of rebar connections should be evaluated due consideration being given to partial safety factors in the relevant national standard; criteria used should be the maximum connection bar force ($F_{s,T}$) and the placement depth (l_v) of the steel bars ((see also annexes 7 to 8).

6 Conclusions

Between week 36, 2008 and week 9, 2009, a total of 27 Ripple Injektionssystem V-Fixs were tested with reinforcing steel sections, steel grade BSt 500S, nominal diameter Ø 8mm to Ø 25 mm, mounted in concrete cylinders, concrete grade ≥ C20/25, to analyse their high-temperature behaviour when subjected to centric tensile loads. This was done to determine the pull-out behaviour.

On the basis of the results produced for the Ripple Injektionssystem V-Fixs, critical temperature-dependent bond stresses $\tau_{crit,T}$ can be specified as values that are on the safe side for a given concrete cover 'c' and for 30-minute up to 180-minute fire resistance times. Among other things, this is used as a basis for the commissioned fire-engineering design concept for rebar connections.

These critical temperature-dependent bond stresses $\tau_{crit,T}$ are used in the fire-engineering design concept for the Ripple Injektionssystem V-Fix in connection with reinforcing bars, nominal diameters Ø 8 mm to Ø 25 mm, to define (in section 5.3) the required concrete cover 'c' for the rebar connection version **OVERLAP JOINT** and (in section 5.4) the required placement depth l_v for the rebar connection version **ANCHORING** as a function of the given fire resistance class.

The load-bearing capacity of the mortar-embedded overlap joints and anchoring connections exposed to a fire on one side in compliance with the ISO 834 standard temperature-time curve must be verified in parallel with verification of the service conditions as specified in the national standards for reinforced concrete. The decisive value will be the higher value respecting the overlap / anchoring length.

7 Notes

7.1 The above assessment only relates to reinforcement connections with nominal diameters Ø 8 mm to Ø 25 mm in connection with the Ripple Injektionssystem V-Fix (tested formulation), due consideration being given to the conditions specified in the client's data sheets for the rebar connection versions **OVERLAP JOINT** and **ANCHORING**.

7.2 The assessment for the rebar connections with the Ripple Injektionssystem V-Fix shall only apply in connection with RC slabs exposed to a fire on one side, whose fire-resistance rating must as a minimum correspond with the fire resistance period of the injection mortar.

7.3 This expert report does not replace the required attestation (General Building Code Test Certificate – abP; type approval – abZ, ETA), but it may be used as a design proposal and thus as a basis for extension of (European) type approvals. A final assessment of the fire resistance rating will be made by the body issuing the certificate in the approval procedure.

7.4 The validity of this expert report will end on 19. October 2014.

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Materialprüfanstalt f. d. Bauwesen Braunschweig MPA BS 3.1

Dipl.-Ing. Maertins
Engineer in charge

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List of annexes (10 annexes)

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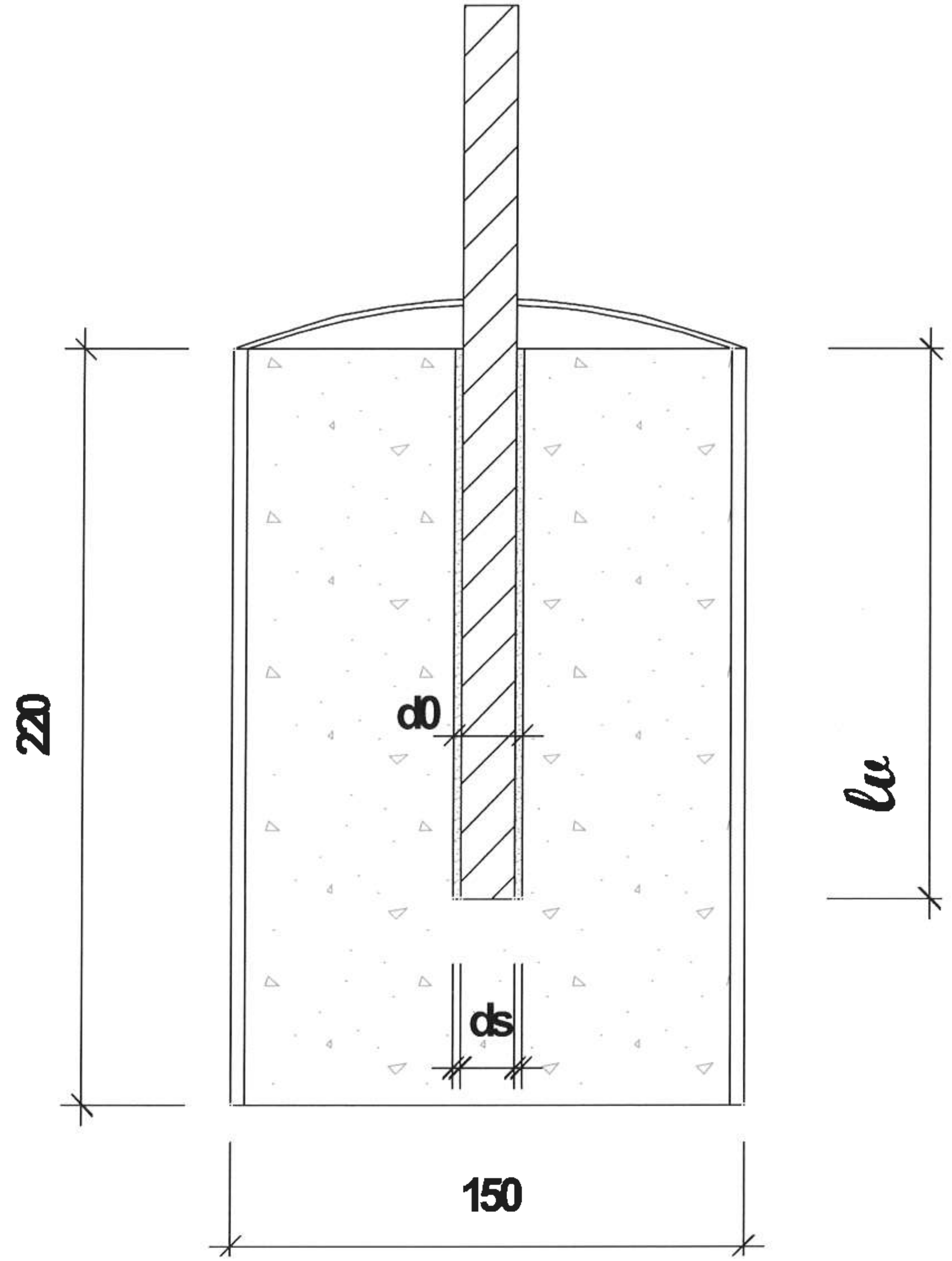
Test aquipment: Electrically heated servohydraulic test aquipment, for the determination of the high-temperature behaviour of the Ripple Injektionssystem V-Fix.

The tests for determination of the general high-temperature behaviour of RC members as described in Beton-Brandschutz-Handbuch [1] were made in test furnaces, in which the specimen had one face exposed to a fire in compliance with the ISO 834 standard temperatur-time curve.

[1] Beton-Brandschutz-Handbuch, Kordina, Meyer-Ottens, Beton-Verlag 1981

Test equipment with built-in specimen



Test arrangement of reinforced steel bar (rebar)	Annex 2 of expert report No. (3526/607/14) - CM
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Figure 1: Overlapping joint for rebar connections of slabs and beams

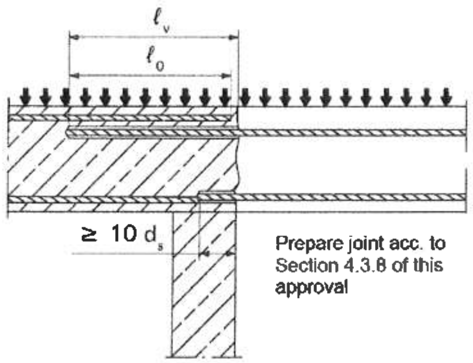


Figure 2: Overlapping joint at a foundation of a wall or column where the rebars are stressed in tension

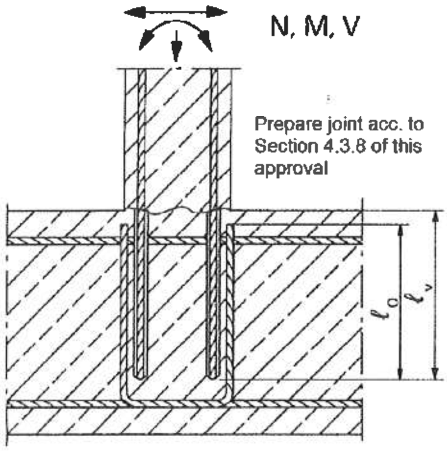


Figure 3: End anchoring of slabs or beams, designed as simply supported

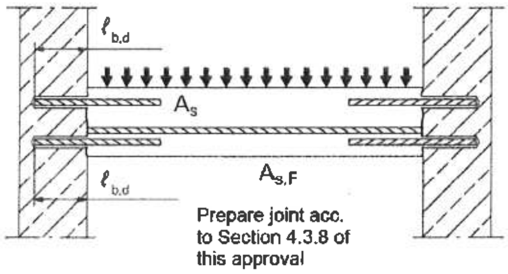


Figure 4: Rebar connection for components stressed primarily in compression. The rebars sre stressed in compression

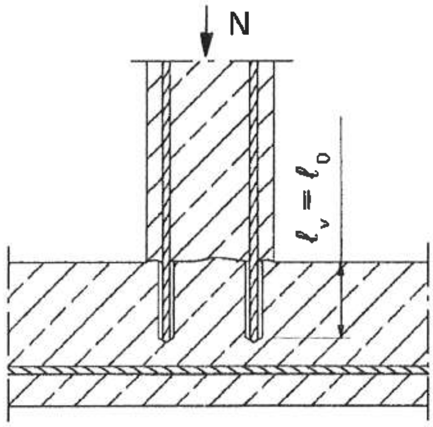
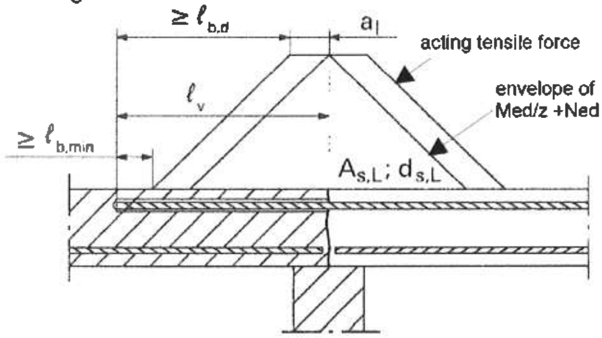


Figure 5: Anchoring of reinforcemend to cover the line of acting tensile force



Note to Figure 1 to 5:
In the figures no transverse reinforcement is plotted, the transverse reinforcement as required by EC 2 shall be present.

The shear transfer between old and new concrete shall be designed according to EC2

General rules for construction and design compare Annex 4.

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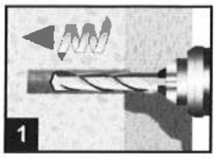
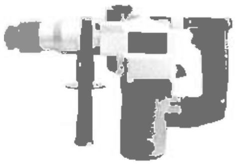
A) Bore hole drilling



1. Drill a hole into the base material to the size and embedment depth required by the selected reinforcing bar with carbide hammer drill (HD) or a compressed air drill (CD).

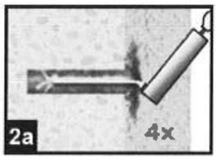


Hammer drill (HD)

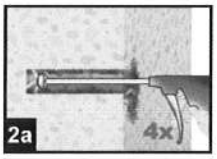
Compressed air drill (CD)

Rebar - Ø	Drill - Ø
d_s	[mm]
8 mm	12
10 mm	14
12 mm	16
14 mm	18
16 mm	20
20 mm	25
22 mm	28
24 mm	32
25 mm	32

B) Bore hole cleaning

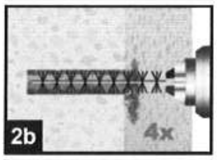


or

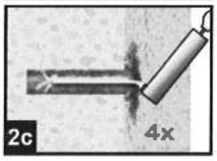


2a. Starting from the bottom or back of the bore hole, blow the hole clean with compressed air or a hand pump a minimum of four times. If the bore hole ground is not reached an extension shall be used.

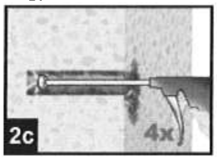
For bore holes deeper then 240 mm, compressed air (min. 6 bar) **must** be used.



2b. Check brush diameter (Table 5) and attach the brush to a drilling machine or a battery screwdriver. Brush the hole with an appropriate sized wire brush > $d_{b,min}$ (Table 5) a minimum of four times.
If the bore hole ground is not reached with the brush, a brush extension shall be used.



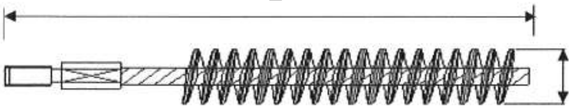
or



2c. Finally blow the hole clean again with compressed air or a hand pump a minimum of four times. If the bore hole ground is not reached an extension shall be used.

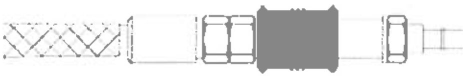
For bore holes deeper then 240 mm, compressed air (min. 6 bar) **must** be used.

Table 5: Cleaning tools



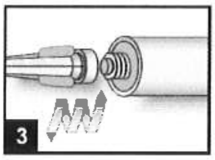
d_s Rebar - Ø	d_0 Drill bit - Ø	d_b Brush - Ø	$d_{b,min}$ min. Brush - Ø	L Total length
(mm)	(mm)	(mm)	(mm)	(mm)
8	12	14	12,5	170
10	14	16	14,5	200
12	16	18	16,5	200
14	18	20	18,5	300
16	20	22	20,5	300
20	25	27	25,5	300
22	28	30	28,5	300
24	32	34	32,5	300
25	32	34	32,5	300

Hand pump (volume 750 ml)

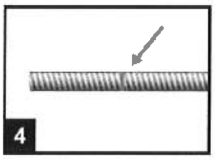


Rec. compressed air tool hand slide valve (min 6 bar)

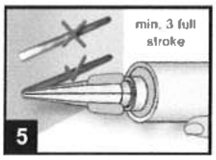
C) Preparation of bar and cartridge



3 Attach the supplied static-mixing nozzle to the cartridge and load the cartridge into the correct dispensing tool.
For every working interruption longer than the recommended working time (Table 7) as well as for every new cartridges, a new static-mixer shall be used.

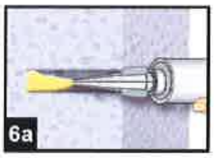


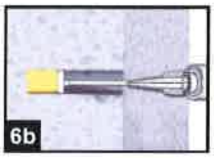
4 Prior to inserting the reinforcing bar into the filled bore hole, the position of the embedment depth shall be marked (e.g. with tape) on the reinforcing bar and insert bar in empty hole to verify hole and depth ℓ_v.
The anchor should be free of dirt, grease, oil or other foreign material.



5 Prior to dispensing into the anchor hole, squeeze out separately the mortar until it shows a consistent grey colour, but a minimum of three full strokes, and discard non-uniformly mixed adhesive components.

D) Filling the bore hole





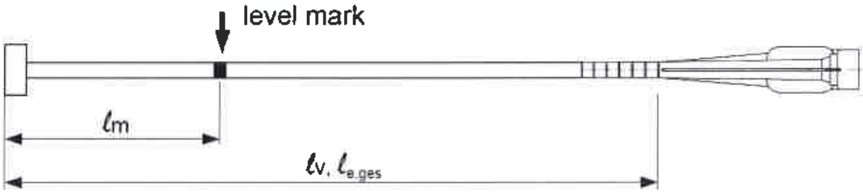
6 Starting from the bottom or back of the cleaned anchor hole fill the hole up to approximately two-thirds with adhesive. Slowly withdraw the static mixing nozzle as the hole fills to avoid creating air pockets. For embedment larger than 190 mm an extension nozzle shall be used.

For overhead and horizontal installation and bore holes deeper than 240 mm a piston plug and the appropriate mixer extension must be used.

Observe the gel-/ working times given in Table 4.

Table 6: Piston plugs, max anchorage depth and mixer extension

Bar size	Drill bit - Ø		Piston plug	Cartridge: coaxial (all), side-by-side (235, 345 ml)				Cartridge: side-by-side (865 ml)	
				Hand or battery tool		Pneumatic tool		Pneumatic tool	
	HD	PD		l_{max}	Mixer extension	l_{max}	Mixer extension	l_{max}	Mixer extension
(mm)	(mm)		No.	(cm)		(cm)		(cm)	
8	12	-	#12	70	VL 10/0,75	80	VL 10/0,75	-	
10	14	-	#14			100			
12	16		#16					120	VL 16/1,8
14	18		#18					140	
16	20		#20					160	
20	25	26	#25	50		70		200	
22	28		#28						
24	32		#32			50			
25	32		#32						



Injection tool must be marked by mortar level mark ℓ_m and anchorage depth ℓ_v resp. $\ell_{e,ges}$ with tape or marker.

Quick estimation: $\ell_m = 1/3 \cdot \ell_v$

Continue injection until the mortar level mark ℓ_m becomes visible.

Optimum mortar volume: $\ell_m = \ell_v$ resp. $\ell_{e,ges} \cdot \left(1{,}2 \cdot \frac{d_s^2}{d_0^2} - 0{,}2\right)$ [mm]

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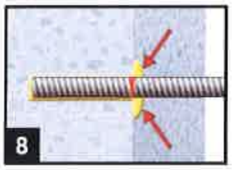
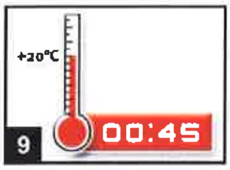
E) Inserting the rebar

7 Push the reinforcing bar into the anchor hole while turning slightly to ensure positive distribution of the adhesive until the embedment depth is reached.

The anchor should be free of dirt, grease, oil or other foreign material.



8 Be sure that the bar is fully seated at the bottom of the hole and that excess mortar is visible at the top of the hole. If these requirements are not maintained, the application has to be renewed.



9 Observe gelling time t_{gel}. Attend that the gelling time can vary according to the base material temperature (see Table 7). It is not allowed to move the bar after geling time t_{gel} has elapsed.
Allow the adhesive to cure to the specified time prior to applying any load. Do not move or load the bar until it is fully cured (attend Table 7). After full curing time t_{cure} has elapsed, the add-on part can be installed.

Table 7: Base material temperature, gelling time and curing time

Concrete temperature	Gelling- / working time[1)]	Minimum curing time in dry concrete	Minimum curing time in wet concrete
	t_{gel}	$t_{cure,dry}$	$t_{cure,wet}$
0°C to +4°C	8[2)] min	420 min	840 min
+5°C to +9°C	6 [2)] min	120 min	240 min
+10°C to +19°C	5[2)] min	80 min	160 min
+20°C to +24°C	4[2)] min	45 min	90 min
+25°C to +29°C	2,5[2)] min	25 min	50 min
+30°C to +40°C	2,5[3)] min	15 min	30 min

[1)] t_{gel}: maximum time from starting of mortar injection to completing of rebar setting.
[2)] Cartridge temperature **must** be between +5°C and +25°C
[3)] Cartridge temperature **must** be below +20°C

Maximum bond stress, τ_T fire resistence time [min] 30	60	90	120	180	Concrete coverage of bonded-in rebar ,c
N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	mm
0,27	0,00	0,00	0,00	0,00	30
0,34	0,00	0,00	0,00	0,00	35
0,44	0,00	0,00	0,00	0,00	40
0,55	0,00	0,00	0,00	0,00	45
0,71	0,26	0,00	0,00	0,00	50
0,86	0,31	0,00	0,00	0,00	55
1,07	0,38	0,00	0,00	0,00	60
1,41	0,46	0,00	0,00	0,00	65
1,96	0,58	0,26	0,00	0,00	70
2,30	0,69	0,31	0,00	0,00	75
	0,85	0,36	0,00	0,00	80
	0,97	0,42	0,25	0,00	85
	1,12	0,50	0,31	0,00	90
	1,31	0,60	0,35	0,00	95
	1,57	0,73	0,41	0,00	100
	1,79	0,85	0,49	0,00	105
	2,07	1,00	0,61	0,25	110
	2,30	1,19	0,71	0,28	115
		1,45	0,85	0,32	120
		1,66	0,99	0,37	125
		1,92	1,16	0,44	130
		2,17	1,38	0,48	135
		2,30	1,67	0,52	140
			1,84	0,59	145
			2,03	0,67	150
			2,23	0,75	155
			2,30	0,85	160
				0,99	165
				1,16	170
				1,38	175
				1,67	180
				1,84	185
				2,03	190
				2,01	195
				2,22	200
				2,30	205

Nominal diameter of rebar	Drill hole diameter	Maximum force of rebar	Anchor depth of rebar	Maximun force[1)] of rebar in conjunction with BERNER REBAR (yieling point fyk = 500 N/mm²) in relation to fire resistence time [min]				
$\max F_{s,T} = \frac{\pi}{4} d_s^2 \bullet \frac{500}{1{,}15 \bullet 1{,}35}$				30	60	90	120	180
d_s	d_0	max $F_{s,T}$	l_v	$F_{s,T}$				
mm	mm	kN	mm	kN	kN	kN	kN	kN
8	12	16,2	80	1,64	0,44	0,12	0,00	0,00
			150	13,04	5,55	2,79	1,64	0,49
			170	16,20	9,17	5,37	3,03	0,96
			210		16,20	12,61	9,21	3,08
			230			16,20	12,82	5,41
			250				16,20	9,03
			290					16,20
10	12	25,3	100	4,99	1,34	0,50	0,21	0,00
			150	16,30	6,93	3,49	2,05	0,62
			190	25,30	15,98	11,24	7,01	2,29
			235		25,30	21,42	17,16	7,89
			255			25,30	21,69	12,41
			275				25,30	16,94
			315					25,30
12	16	36,4	120	11,42	3,25	1,45	0,75	0,16
			180	27,71	16,46	10,77	6,20	2,02
			215	36,40	25,96	20,27	15,17	5,31
			255		36,40	32,49	26,02	14,90
			275			36,40	31,45	20,33
			295				36,40	25,76
			335					36,40
14	18	49,6	140	19,66	7,13	3,50	2,02	0,58
			200	38,66	25,54	18,90	12,94	4,14
			235	49,60	36,62	29,98	24,03	11,05
			280		49,60	44,23	38,28	25,30
			305			49,60	46,19	33,21
			320				49,60	37,96
			355					49,05

1) Intermediate values may be obtained by linear interpolation. Exrapolation is not permitted

Nominal diameter of rebar	Drill hole diameter	Maximum force of rebar	Anchor depth of rebar	Maximun force[1)] of rebar in conjunction with BERNER REBAR (yieling point fyk = 500 N/mm²) in relation to fire resistence time [min]				
$\max F_{s,T} = \frac{\pi}{4} d_s^2 \bullet \frac{500}{1{,}15 \bullet 1{,}35}$				30	60	90	120	180
d_s	d_0	max $F_{s,T}$	l_v	$F_{s,T}$				
mm	mm	kN	mm	kN	kN	kN	kN	kN
16	**20**	**64,8**	160	29,70	14,71	7,79	4,47	1,39
			240	58,66	43,67	36,08	29,27	14,44
			260	64,80	50,90	43,31	36,51	21,67
			300		64,80	57,79	50,98	36,15
			320			64,80	58,22	43,39
			340				64,80	50,63
			380					64,80
20	**25**	**101,2**	200	55,23	36,49	27,00	18,49	5,92
			250	77,84	59,11	49,62	41,11	22,57
			305	101,20	83,99	74,50	65,99	47,45
			345		101,20	92,60	84,09	65,54
			365			101,20	93,13	74,59
			385				101,20	83,64
			425					101,20
25	**32**	**158,1**	250	97,31	73,88	62,02	51,39	28,21
			300	125,58	102,16	90,30	79,66	56,48
			360	158,10	136,09	124,23	113,59	90,41
			400		158,10	146,85	136,21	113,03
			420			158,10	147,52	124,34
			440				158,10	135,65
			480					158,10

1) Intermediate values may be obtained by linear interpolation. Exrapolation is not permitted