Hilti HIT Injection Adhesive 4-hours Fire Test Reports

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The Fire Performance of Various Types of Anchor Fixing Systems for Use in Concrete Structures: Hilti HIT-HY 150 and HIT-RE 500 Injection Systems for Rebar Connection

Report for

Hilti Entwicklung Befestigungstechnik GmbH
Hiltistrasse 22
86916 Kaufering
Germany

Warrington FIRE research
CONSULTANCY•TESTING

The Professionals in Fire Safety

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1 Introduction

This report provides a considered opinion regarding the fire performance of various types of anchor fixing systems for use in concrete structures when subjected to tests utilising the general principles of BS 476: Part 20: 1987.

The report considers the test procedures and subsequent data obtained from tests conducted at the Institut Für Baustoffe Massivbau und Brandschutz, Technische Universität Braunschweig (IBMB), Germany, and the general principles of BS 476: Part 20: 1987.

This report refers to test data from IBMB carried out on Hilti HIT-HY150 and HIT-RE 500 injection adhesive used to make connections in concrete floor structures via reinforcing bars (referred to as rebar).

The data referred to in Sections 7 and 8 of this report has been considered for the purpose of this appraisal which has been prepared in accordance with the general principles of the Fire Test Study Group Resolution No. 82: 2001.

2 Assumptions

It is assumed that the concrete elements into which the various types of rebar are installed will be constructed in accordance with BS 8110: Part 2: 1985 and have a minimum compressive strength of 25 N/mm^2.

The fire performance rating of the injection systems is assumed to apply to reinforced concrete elements which have been designed to give at least the same period of fire resistance as that for the injection system.

The injection systems are assumed to be installed correctly and in accordance with Hilti Entwicklung Befestigungstechnik GmbH installation instructions.

It is assumed that the steel for the reinforcing bar is at least equal in strength to that used for the tested arrangements or as otherwise indicated in this report.

In addition, it is assumed that the application of the injection adhesive is identical to that adopted for the tested arrangements and that the fire test exposure is in one direction only.

3 Hilti Systems

3.1 Hilti HIT-HY 150 Injection System

The Hilti HIT-HY 150 injection system is an adhesive mortar which is used for making rebar connections in steel reinforced concrete structure. The adhesive system is based on a modified epoxy acrylate resin and on the hydraulic cement reaction.

The appropriate steel rebar diameter ranges from 8mm to 25mm and the insertion depth (anchorage) is calculated on the basis of the rebar diameter multiplied by 10.

The Hilti system may be installed in two arrangements, an overlapping method whereby the connecting rebar is inserted within a prepared hole such that it overlaps existing rebar and an anchoring arrangement.

A full description is given in the appropriate test report referred to in Section 7.

3.2 Hilti HIT-RE 500 Injection System

The Hilti HIT-RE 500 injection system is a two component adhesive mortar which is used for making rebar connections in steel reinforced concrete structure. The adhesive system is based on an epoxy resin and an amine based hardener.

The appropriate steel rebar diameter ranges from 8mm to 40mm and the insertion depth is calculated on the basis of the rebar diameter multiplied by 10 (The tests included a reduced insertion depth to ensure ultimate performance of the system could be assessed).

The Hilti system may be installed in two arrangements, an overlapping method whereby the connecting rebar is inserted within a prepared hole such that it overlaps existing rebar and an anchoring arrangement.

A full description is given in the appropriate test report referred to in Section 7.

4 Test Data/Analysis Procedure

The test data which provides evidence in support of this assessment is given in test reports Nr. 3162/6989 and Nr 3357/0550-5 prepared by IBMB.

There are at present no published British Standards applicable to the testing and determination of the performance of rebar connection systems for use in structural grade concrete which may be subjected to fire.

The test evidence referred to in this report has been provided from an extensive testing programme carried out in accordance with DIN 4102: Part 2: 1977 at the Institut Für Baustoffe, Technische Universität Braunschweig. The heating conditions of DIN 4102: Part 2: 1977 are largely based upon those referred to in ISO 834, upon which the heating and test procedures given in BS 476: Part 20: 1987 are also based.

Therefore, the heating conditions of the two testing procedures are sufficiently similar to allow for correlation.

In the absence of a British Standard test method to determine the performance of fixings under fire it would seem appropriate to subject the injection systems to standardised heating conditions while carrying either some or all of their designated load and derive a performance ratings for the systems.

The testing referred to in Nr 3162/6989 and Nr 3357/0550-5 was conducted on both 'overlap' and 'anchoring' arrangements with various diameter steel rebars.

Briefly, the rebars were installed in small concrete cylinders using the referenced Hilti injection systems applied in accordance with the manufacturer's instructions. The rebars were loaded by hydraulic means to induce tensile stress in the rebar and the connection system. The cylinders were exposed to the heating conditions of DIN 4102: Part 2: 1977 (similar to BS 476: Part 20: 1987).

Thermocouples were used to measure the temperature profile of the bonding material (generally at the top and bottom of the hole) and the displacement of the rebar was also measured. A full description of the test procedure is given in the test reports.

The performance of the system was defined in relation to the failure temperature of the adhesive system under load (termed the bond stress).

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The test data, the method of analysis and the results of the analysis are fully presented in reports Nr 3162/6989 (including supplementary letter 120/2) and Nr 3357/0550-5.

The test reports provided graphs showing plots of failure temperature against the critical temperature dependent bond stress. The resulting curve was drawn such that it was below the test values and therefore represented a conservative approach. This conservative curve was adopted in the analysis for each injection system.

The curve was used to develop specifications of limiting bond stress against concrete cover for various fire resistance periods using an established temperature/concrete depth relationship.

The limiting stress was recalculated to give a limiting load appropriate to the rebar diameter for various fire resistance periods and anchorage length.

Tables 1 to 2 show the limiting load in relation to rebar diameter, anchorage length for various fire resistance periods for each of the injection systems.

The tables relate to a minimum yield strength of rebar of 460N/mm^2 and partial safety factors equal to at least those specified in BS 8110: Part 1: 1987.

5 Conclusion

There is not at present a British Standard test method for determining the ability of fixing systems to support their recommended service loads under fire resistance test conditions.

In the absence of a recognised test procedure a series of tests utilising heating conditions comparable with those of BS 476: Part 20: 1987 has been performed on the Hilti HIT-HY 150 and Hilti HIT-RE 500 injection systems to determine their ability to make connections via reinforcing bars in concrete structures required to provide fire resistance.

The data provided by the test series has been analysed with respect to details as given in this supplement and performance ratings for the connection system relating to 30 minutes to 240 minutes fire test exposure have been derived.

The results of the analysis appropriate to rebars of 8mm to 25mm diameters in the case of HIT-HY 150 and 8mm to 40mm in the case of HIT-RE 500 are summarised in Tables 1 and 2.

6 Validity

This assessment is issued on the basis of test data and information available at the time of issue. If contradictory evidence becomes available to WFRC the assessment will be unconditionally withdrawn and Hilti Entwicklung Befestigungstechnik GmbH will be notified in writing.

Similarly the assessment is invalidated if the assessed construction is subsequently tested because actual test data is deemed to take precedence over an expressed opinion. The assessment is valid initially for a period of five years, i.e. until 1st October 2007 at which time it is recommended that it be returned for re-appraisal.

This appraisal is only valid provided that no other modifications are made to the construction other than those described in this report.

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7 Summary of Primary Supporting Data

Institut Für Baustoffe, Massivbau und Brandschutz (Germany)
Report Reference Nr. 3162/6989

Latest report on a number of fire tests, in accordance with DIN 4102: Part 2: 1977, to determine the performance of the Hilti HIT-HY 150 rebar connection system.
Test dates : Between 1994 and 1999.

Institut Für Baustoffe, Massivbau und Brandschutz (Germany)
Supplementary Letter 120/2 to Report Reference Nr. 3162/6989

The performance of the Hilti HIT-HY 150 rebar connection system in relation to BS 8110: Part 1: 1997.

Institut Für Baustoffe, Massivbau und Brandschutz (Germany)
Report Reference Nr. 3357/1550-5

Latest report on a number of fire tests, in accordance with DIN 4102: Part 2: 1977, to determine the performance of the Hilti HIT-RE 500 rebar connection system.
Test dates : Between 2000 and 2001.

8 Summary of Secondary Supporting Data

BS 476: Part 20: 1987

Fire tests on building materials and structures. Method for determination of the fire resistance of elements of construction (general principles).

BS 8110: Part 1: 1997
Structural use of concrete Part 1. Code of practice for design and construction.

DIN 4102-, 1977-09

Fire behaviour of building materials and building components: definitions, requirements and tests on building components.

9 Declaration by Hilti Entwicklung Befestigungstechnik GmbH

We the undersigned confirm that we have read and complied with the obligations placed on us by the UK Fire Test Study Group Resolution No. 82: 2001.

We confirm that the component or element of structure, which is the subject of this assessment, has not to our knowledge been subjected to a fire test to the Standard against which the assessment is being made.

We agree to withdraw this supplement from circulation should the component or element of structure be the subject of a fire test to the Standard against which this assessment is being made.

We are not aware of any information that could adversely affect the conclusions of this assessment.

If we subsequently become aware of any such information we agree to cease using the supplement and ask Warrington Fire Research Centre to withdraw the assessment.

Signed: .... **Dr. Franz Böhm**
Head of Hilti Development Fastening Systems

For and on behalf of: Hilti Entwicklung Befestigungstechnik GmbH.

10 Signatories

Prepared by: P.W. Crewe ....* **P W Crewe**

Reviewed by: .... ***C W Miles**

This report is not valid unless it incorporates the declaration duly signed by the applicant. This is included in Section 9 of this report
*For and on behalf of Warrington Fire Research Centre.

Report Issued: 25th September 2002

Issue 2 : Typing error on Table 1, Page 8

Table 1 Maximum Rebar Force for HIT-HY 150 Injection System

Nominal rebar dia Mm	Drill hole dia mm	Max force of rebar kN	Anchorage depth of rebar	Maximum force of rebar in conjunction with injection system for fire resistance period kN					
			mm	30 mins	60 mins	90 mins	120 mins	180 mins	240 mins
8	10	15.73	65	1.96	0.74	0.19	0.04	-	-
			80	3.54	1.51	0.58	0.25	-	-
			95	6.18	2.49	1.26	0.69	0.11	-
			115	9.70	4.41	2.43	1.65	0.50	0.15
			150	15.73	10.13	6.13	4.05	2.09	1.06
			185		15.73	12.29	9.45	4.29	2.84
			205			15.73	12.97	5.69	4.15
			225				15.73	7.38	5.81
			275					15.73	14.02
			285						15.73
10	12	24.58	80	4.43	1.88	0.72	0.31	-	-
			100	8.83	3.55	1.88	1.10	0.22	-
			120	13.23	6.22	3.46	2.42	0.82	0.28
			140	17.62	10.46	5.62	4.12	1.92	0.88
			175	24.58	18.16	13.16	9.61	4.52	2.83
			205		24.58	19.76	16.21	7.12	5.18
			230			24.58	21.71	9.93	7.95
			245				24.58	13.07	10.93
			300					24.58	23.03
			310						24.58
12	16	35.39	95	9.27	3.73	1.88	1.04	0.17	-
			120	15.87	7.46	4.15	2.90	0.98	0.34
			145	22.47	13.87	7.97	5.50	2.71	1.32
			195	35.39	27.07	21.07	16.81	7.46	5.20
			230		35.39	30.31	26.05	11.91	9.54
			250			35.39	31.33	17.00	14.44
			270				35.39	22.28	19.72
			320					35.39	32.91
			330						35.39
14	18	48.17	110	15.44	6.73	3.65	2.38	0.62	0.13
			140	24.67	14.65	7.87	5.76	2.68	1.23
			170	33.91	23.88	16.89	11.92	5.76	3.47
			220	48.17	39.28	32.28	27.31	11.92	9.19
			250		48.17	41.52	36.55	19.84	16.85
			275			48.17	44.25	27.53	24.54
			290				48.17	32.15	29.16
			345					48.17	46.09
			355						48.17
16	20	62.92	130	24.68	13.22	6.99	5.18	2.11	0.85
			160	35.24	23.78	15.78	10.35	5.33	2.97
			190	45.79	34.33	26.34	20.66	9.25	6.28
			240	62.92	51.92	43.93	38.25	19.15	15.73
			275		62.92	56.25	50.57	31.47	28.05
			295			62.92	54.60	38.50	35.09
			315				62.92	45.54	42.12
			365					62.69	59.72
			375						62.92

Minimum yield strength of rebar 460 N/mm^2.
Intermediate values may be obtained by linear interpolation. No extrapolation allowed

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Table 1 Continued Maximum Rebar Force for HIT-HY 150 Injection System

Nominal rebar dia mm	Drill hole dia mm	Max force of rebar kN	Anchorage depth of rebar	Maximum force of rebar in conjunction with injection system for fire resistance period kN					
			mm	30 mins	60 mins	90 mins	120 mins	180 mins	240 mins
20	25	98.31	160	44.05	29.72	19.73	12.94	6.66	3.71
			200	61.64	47.31	37.32	30.22	13.32	9.49
			285	98.31	84.70	74.71	67.61	43.73	39.46
			320		98.31	90.10	83.00	59.13	54.85
			340			98.31	91.80	67.92	63.65
			355				98.31	74.52	70.25
			410					98.31	94.44
			420						98.31
25	30	153.61	200	77.05	59.14	46.65	37.78	16.65	11.86
			250	104.54	86.63	74.14	65.27	35.42	30.08
			340	153.61	136.11	123.62	114.75	84.90	79.58
			375		153.61	142.86	133.99	104.14	98.80
			395			153.61	144.98	115.14	109.80
			415				153.61	126.14	120.79
			465					153.61	148.28
			475						153.61

Minimum yield strength of rebar 460 N/mm^2.
Intermediate values may be obtained by linear interpolation. No extrapolation allowed

Table 2 Maximum Rebar Force for HIT-RE 500 Injection System

Nominal rebar dia mm	Drill hole dia mm	Max force of rebar kN	Anchorage depth of rebar	Maximum force of rebar in conjunction with injection system for fire resistance period kN					
			mm	30 mins	60 mins	90 mins	120 mins	180 mins	240 mins
8	10	15.73	65	1.38	0.57	0.19	0.05	-	-
			80	2.35	1.02	0.47	0.26	-	-
			95	3.87	1.68	0.88	0.55	0.12	-
			115	7.30	3.07	1.71	1.14	0.44	0.18
			150	15.73	8.15	4.59	3.14	1.41	0.80
			180		15.73	9.99	6.75	2.94	1.70
			205			15.73	12.38	5.08	2.86
			220				15.73	6.95	3.82
			265					15.73	8.57
			305						15.73
10	12	24.58	80	2.94	1.27	0.59	0.33	-	-
			100	5.68	2.45	1.31	0.85	0.24	-
			120	10.66	4.44	2.48	1.68	0.68	0.31
			140	17.57	7.76	4.38	2.99	1.33	0.73
			165	24.58	15.06	8.50	5.79	2.58	1.50
			195		24.58	17.63	12.18	5.12	2.93
			220			24.58	20.66	8.69	4.78
			235				24.58	11.80	6.30
			280					24.58	13.86
			320						24.58
12	16	35.39	95	5.80	2.52	1.32	0.83	0.18	-
			120	12.79	5.33	2.97	2.01	0.82	0.37
			145	23.16	10.68	6.02	4.12	1.84	1.03
			175	35.39	22.22	13.20	8.94	3.93	2.26
			210		35.39	27.38	20.65	8.47	4.74
			230			35.39	28.94	12.80	6.90
			250				35.39	19.13	9.89
			290					35.39	19.70
			330						35.39
14	18	48.17	110	10.92	4.65	2.55	1.70	0.61	0.20
			140	24.60	10.87	6.13	4.19	1.86	1.03
			170	39.12	23.50	13.55	9.20	4.07	2.37
			190	48.17	33.18	22.27	15.10	6.43	3.69
			225		48.17	39.20	31.34	13.48	7.34
			245			48.17	41.02	20.20	10.56
			260				48.17	27.07	13.75
			305					48.17	29.66
			345						48.17
16	20	62.92	130	22.59	9.42	5.30	3.61	1.56	0.80
			160	39.17	21.33	11.95	8.15	3.65	2.11
			190	55.76	37.92	25.45	17.25	7.35	4.22
			205	62.92	46.21	33.74	24.76	10.16	5.73
			240		62.92	53.10	44.12	20.88	11.04
			260			62.92	55.17	30.94	15.72
			275				62.92	39.23	20.36
			320					62.92	42.08
			360						62.92

Minimum yield strength of rebar 460 N/mm^2.
Intermediate values may be obtained by linear interpolation. No extrapolation allowed

Table 2 Continued Maximum Rebar Force for HIT-RE 500 Injection System

			Anchorage depth of rebar	Maximum force of rebar in conjunction with injection system for fire resistance period kN					
			mm	30 mins	60 mins	90 mins	120 mins	180 mins	240 mins
20	25	98.31	160	48.97	26.67	14.93	10.18	4.56	2.64
			200	76.61	54.31	38.73	24.50	11.42	6.48
			235	98.31	78.50	62.92	51.69	23.60	12.60
			265		98.31	83.65	72.42	42.13	21.43
			290			98.31	89.70	59.41	32.83
			305				98.31	69.77	42.23
			350					98.31	73.33
			390						98.31
25	30	153.61	200	95.77	67.89	48.41	31.37	14.27	8.10
			250	138.95	111.09	91.60	77.57	39.86	20.61
			270	153.61	128.37	108.88	94.85	56.98	29.19
			300		153.61	134.80	120.77	82.90	48.55
			325			153.61	142.37	104.50	70.07
			340				153.61	117.45	83.02
			385					153.61	121.90
			425						153.61
28	35	192.68	225	131.45	100.23	78.41	62.69	26.95	14.69
			250	155.64	124.42	102.60	86.88	44.64	23.08
			290	192.68	163.12	141.30	125.58	83.17	45.95
			325		192.68	175.17	159.45	117.04	78.47
			345			192.68	178.80	136.39	97.83
			360				192.68	150.90	112.34
			405					192.68	155.88
			445						192.68
32	40	251.67	255	183.40	147.72	122.78	104.82	56.35	28.80
			280	211.05	175.37	150.43	132.47	83.99	44.34
			320	251.67	219.60	194.66	176.70	128.23	84.15
			350		251.67	227.84	209.87	161.40	117.33
			375			251.67	237.52	189.05	144.98
			390				251.67	205.63	161.56
			435					251.67	211.33
			475						251.67
36	44	318.52	290	248.97	209.73	181.67	161.46	106.93	59.10
			320	287.19	247.05	218.99	198.79	144.25	94.67
			350	318.52	284.37	256.32	236.11	181.58	132.00
			380		318.52	293.64	273.43	218.90	169.32
			400			318.52	298.31	243.78	194.20
			420				318.52	268.66	219.08
			465					318.52	275.06
			500						318.52
40	47	393.23	320	319.10	274.50	243.33	220.87	160.28	105.19
			350	360.57	315.97	284.80	262.34	201.75	146.66
			375	393.23	350.53	319.35	296.90	236.31	181.22
			410		393.23	367.73	345.28	284.69	229.60
			430			393.23	372.93	312.33	257.25
			445				393.23	333.07	277.98
			490					393.23	340.18
			530						393.23

Minimum yield strength of rebar 460 N/mm^2.
Intermediate values may be obtained by linear interpolation. No extrapolation allowed

WF Report No. 183223

18th May 2009

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Review of Assessment Referenced WFRC Report No. C121086

1 Introduction

WFRC Report No. C121086 presents a considered opinion regarding the expected fire performance of various types of anchor fixing systems for use in concrete structures when subjected to tests utilising the general principles of BS 476: Part 20: 1987.

The report concluded that there was not a British Standard test method for determining the ability of fixing systems to support their recommended service loads under fire resistance test conditions.

In the absence of a recognised test procedure a series of tests utilising heating conditions comparable with those of BS 476: Part 20: 1987 was been performed on the Hilti HIT-HY 150 and Hilti HIT-RE 500 injection systems to determine their ability to make connections via reinforcing bars in concrete structures required to provide fire resistance.

The data provided by the test series was analysed with respect to details as given in the supplement and performance ratings for the connection system relating to 30 minutes to 240 minutes fire test exposure were derived.

The results of the analysis appropriate to rebars of 8mm to 25mm diameters in the case of HIT-HY 150 and 8mm to 40mm in the case of HIT-RE 500 were summarised in Tables 1 and 2.

2 Confirmation of Specification

It has been confirmed by Hilti Entwicklungsgellschaft mbH, there have been no changes to the specification appraised in the original report referenced WFRC Report No. C121086.

3 Conclusions

The data used for the original appraisal has been re-examined and found to be satisfactory.

Although there is now also the possibility of European Technical Approval for fixings of the types described in WFRC No. C121086, the procedures adopted for the original assessment have also been re-examined and are similar to those currently in use.

Therefore, with respect to the assessment of performance given in WFRC Report No. C121086, the contents should remain valid until the 1st June 2014.

4 Validity

This review is based on information used to formulate the original test report. No other information or data has been submitted by Hilti Entwicklungsgellschaft mbH, which could affect this review.

The original appraisal report was performed in accordance with the principles of the UK Fire Test Group Resolution 82: 2001. This review has therefore been conducted using these principles.

Performed by:

C. Johnson
Senior Certification Engineer
Technical Department
Bodycote warringtonfire

Reviewed By:

D. Hankinson
Senior Certification Engineer
Technical Department
Bodycote warringtonfire

1st Issue

Expert Assessment

No. 3162/6989 -Nau- dated July 16, 1999

Expert assessment on a technical design concept for rebar connections suitable for fire protection using reinforcing steel bars of BSt 500 S grade, 8 to 25 mm in diameter, and Hilti HIT-HY 150 injection adhesive

Client : HILTI Corporation
Business unit anchor, chemical section / north office
FL - 9494 Schaan
Principality of Liechtenstein

Order : verbal on May 5, 1999

This expert assessment consists of 20 pages and 4 annexes.

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Deutscher Akkreditierungs Rat

Nach DIN EN ISO/IEC 17025 akkreditierte Prüflaboratorien: DAP-PL-2204.01 · DAP-PL-2204.02 · DAP-PL-2204.03 · DAP-PL-2204.04 · DAP-PL-2204.05
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Die Akkreditierungen gelten für die in den Urkunden aufgeführten Prüfverfahren

1 Reason and Order

With request dated May 5, 1999, the Hilti Corporation assigned the MPA Braunschweig with the task of producing an expert assessment on a technical design concept for rebar connections suitable for fire protection using reinforcing steel bars of BSt 500 S grade, 8 to 25 mm in diameter, and Hilti HIT-HY 150 injection adhesive in reinforced-concrete slabs and wall sections exposed to fire on one side.

To lay the foundations for the determination of the thermomechanical properties, high-temperature investigations were carried out using small specimens (concrete cylinders 250 mm long and 150 mm in diameter) which were subjected to pure tensile loading to ascertain the pull-out behaviour in accordance with ISO 834.

2 Description of experimental investigations and results

2.1 Description of experimental investigations

2.1.1 Description of tested arrangements

The tested Hilti HIT-HY 150 injection system is a means of making fastenings without expansion forces when set in normal concrete with quarzitic aggregates and subjected primarily to a static (dead) load.

Hilti HIT-HY 150 is an injection adhesive anchor system with a working principle based on utilisation of the bond between steel, the two-component injection adhesive and concrete. It consists of a ready for use, prepared two-component injection adhesive with combined organic and inorganic binders, i.e. a hybrid system, which is contained in a dual foil pack whose contents are injected into a drilled hole through an interchangeable, static forced mixer by a dispenser. The injection adhesive is a binder system that is based on urethane methacrylate resin and on cement. Steel bar material of the grade BSt 500 S with a diameter of 12 mm was used as the reinforcing steel. Technical data sheets from the client provide a ruling on setting and loading the fastenings made with the Hilti HIT-HY 150 injection system. A type approval for the Hilti HIT-HY 150 injection system has been applied for and is currently being dealt with by the Deutsches Institut für Bautechnik, Berlin, Germany.

Structural details regarding the range of applications for the Hilti HIT-HY 150 injection system are shown in annex 1 of this expert assessment.

A total of 22 rebars were set with the Hilti HIT-HY 150 injection system in concrete cylinders of the grade ≥ C 20/25, 150 mm in diameter and with a length of 250 mm. They were tested subjected to pure tensile loading to determine the pull-out behaviour at high temperature and to provide input

...

for developing a technical design concept for the use of rebar connections suitable for fire protection.

The installation of the rebars by means of Hilti HIT-HY 150 injection adhesive was carried out in accordance with the clients technical data sheets while using the pertaining installation tools specified in these sheets, i.e. rotary hammer, drill bit, dispenser and static, forced mixer.

The pure tensile load was transferred to the rebars of BSt 500 S steel via the press cylinder of the servo-hydraulic, high-temperature test rig.

Further details regarding the installation of the Hilti HIT-HY 150 injection system in the test rig can be seen in annexes 2 and 3 of this expert assessment.

2.1.2 Test arrangement and realization

The tests were carried out in an electrically heated, servo-hydraulic, high-temperature test rig. A hole about 120 mm long with a nominal diameter of 14 or 16 mm was drilled in the middle of a base surface of each concrete cylinder. After the holes had been cleaned, Hilti HIT-HY 150 injection adhesive was injected and the rebars set in the holes at an anchorage depth, l = 10 x Ø 12 mm = 120 mm. Thermocouples were fastened to each rebar before its insertion into the hole so that the temperature in the Hilti HIT-HY 150 injection adhesive could be measured at depths of approximately 10 mm and 120 mm below the concrete base surface.

Further details of the test arrangement concerning the rebars (BSt 500 S, 12 mm in diameter) set with Hilti HIT-HY 150 injection adhesive may be found in annex 4 of this expert assessment.

The test rig temperatures were increased and measured using thermocouples applied to the circumferential surface of the concrete cylinders. During the tests, displacement of the rebars relative to the concrete base surface was continually registered using a measuring device outside the furnace.

2.2 Test results

In the period from calendar week 27, 1994, to calendar week 41, 1998, 22 test specimens made with Hilti HIT-HY 150 injection adhesive and rebar sections of BSt 500 S steel, 12 mm in diameter, set in concrete cylinders of the grade ≥ C 20/25 were tested at high-temperature and subjected to pure tensile loading, to determine the pull-out behaviour as well as to develop a technical design concept suitable for fire protection according to ISO 834 for the use of rebar connections in reinforced-concrete slabs or wall sections exposed to fire on one side.

The results obtained when testing the Hilti HIT-HY 150 injection system are given in the following table 1 (see page 4).

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Table 1 : Summary of test results of the Hilti HIT-HY 150 injection adhesive in conjunction with rebars, 12 mm in diameter, of the steel grade BSt 500 S set at an anchorage depth, l = 10 x Ø 12 mm = 120 mm

Date of testing	Diameter of drill hole [mm]	Actual load N [kN]	Failure [1) Time [min]	Failure [1) Temperature [°C]
July 7, 1994	16,3	65,00	5	20 [2)
July 8, 1994		13,50	35	120
July 11, 1994		13,50	129	120
July 12, 1994		6,75	295	300
July 13, 1994	14,3	13,50	90	125
August 1, 1994		13,50	52	125
August 2, 1994	16,3	3,80	235	325
August 3, 1994		5,20	204	320
August 4, 1994		6,00	183	300
August 5, 1994		6,80	167	285
August 8, 1994		20,00	79	100
August 9, 1994		40,00	57	70
August 10, 1994		10,00	132	190
August 11, 1994		11,60	119	160
August 12, 1994		50,00	52	60
August 15, 1994		8,50	147	200
August 16, 1994		30,00	68	90
September 16, 1998		13,60	100	130
September 18, 1998		7,20	180	260
October 2, 1998		11,00	130	164
October 5, 1998		3,10	220	364
October 8, 1998		62,60	5	18 [2)

1) Bond failure of the mortar due to a disproportional high increase in displacement while subjecting to constant load.

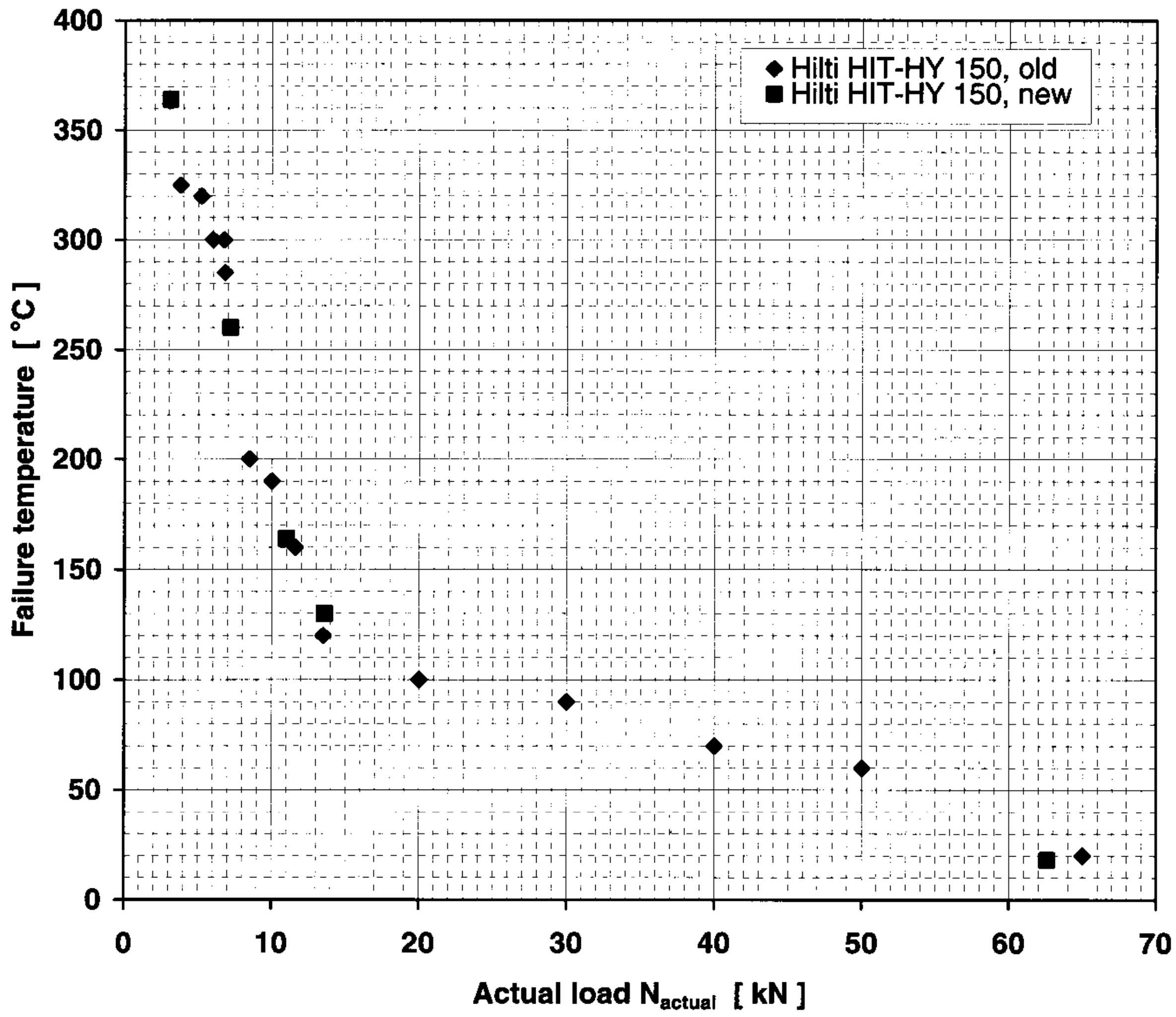
2) The test was carried out at room temperature.

...

The test results of Hilti HIT-HY 150 injection adhesive used with rebar sections of the steel grade BSt 500 S, 12 mm in diameter, set in reinforced concrete of the grade ≥ C 20/25, are shown graphically in the following figure 1 as a function of the actual load.

To verify the compatibility concerning the required load redistribution caused by the decomposition of the injection adhesive due to temperature during the exposure to fire, two rebar sections of BSt 500 S steel, 8 mm in diameter, set at an anchorage depth, l = 350 mm (= 43.75 x Ø 8 mm), were tested for their fire behaviour in accordance with ISO 834 subjected to a pure tensile load of 14.6 kN on July 2, 1998, at the MPA Braunschweig. After exposure to fire for 96 and 100 minutes, the rebar failed in each specimen by breaking outside the concrete.

Fig. 1 : Graphical presentation of test results obtained with Hilti HIT-HY 150 injection system using rebar sections of the steel grade BSt 500 S, 12 mm in diameter, set at an anchorage depth, l = 10 x Ø 12 mm = 120 mm, as a function of the actual load



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3 Technical design concept suitable for fire protection

3.1 General aspects

Based on the results when testing the high-temperature behaviour of Hilti HIT-HY 150 injection system, as given in section 2, a technical design concept for use of rebar connections suitable for fire protection according to ISO 834, made in reinforced-concrete slabs exposed to fire on one side, had to be developed in accordance with the clients request.

This technical design concept should include both rebar connection versions, namely "**overlap joint**" and "**anchored rebar**".

3.2 Fundamentals and literature

Fundamentals for the technical design concept suitable for fire protection are as follows :

[1] DIN 1045, 1988-12, (Concrete and reinforced concrete, design and construction)

[2] DIN V ENV 1992 part 1-1 (issue 1992-06), Eurocode 2 (Planning of reinforced-concrete and prestressed-concrete structures; part 1 : fundamentals and application regulations for building construction)

[3] DIN 4102 - 2 : 1977-09 (ISO 834), (Behaviour in fire of building materials and components. Building components, terms, requirements and tests)

[4] (Concrete-fire protection handbook). Prof. Dr.-Ing. Dr.-Ing. h.c. K. Kordina and Dr.-Ing. C. Meyer-Ottens, issue 1981

As the design of rebar connections in accordance with DIN 1045 and Eurocode 2 is based on the utilisation of bond stresses, the test results were depicted in fig. 3 (see page 8) as function values plotted against the failure temperature and the corresponding bond stress, actual τ, in order to achieve conformity, and in keeping with the results of testing the Hilti HIT-HY 150 injection adhesive as per table 1 (see page 4) and fig. 1 (see page 5). Based on this, a design curve, kept on the safe side and below the actual failure values, was configured in fig. 4 (see page 8) under consideration of the experience gained while testing and the results given in fig. 3.

...

Using the knowledge about the heat-up behaviour of concrete as per [4] (see fig. 2), the design curve from fig. 4 (see page 8) and further experiences from testing normal concrete with quarzitic aggregates, critical temperature-dependent bond stresses, $\tau_{crit,T}$, were provided on the safe side in table 2 (see page 9) in relation to the respective concrete coverage, c, for fire resistance times from 30 to 180 minutes.

Fig. 2 : **Temperature distribution as per DIN 4102 - 2 : 1977-09 (ISO 834) in slabs and wall sections of normal concrete with quarzitic aggregates exposed to fire on one side; from [4], page 141**

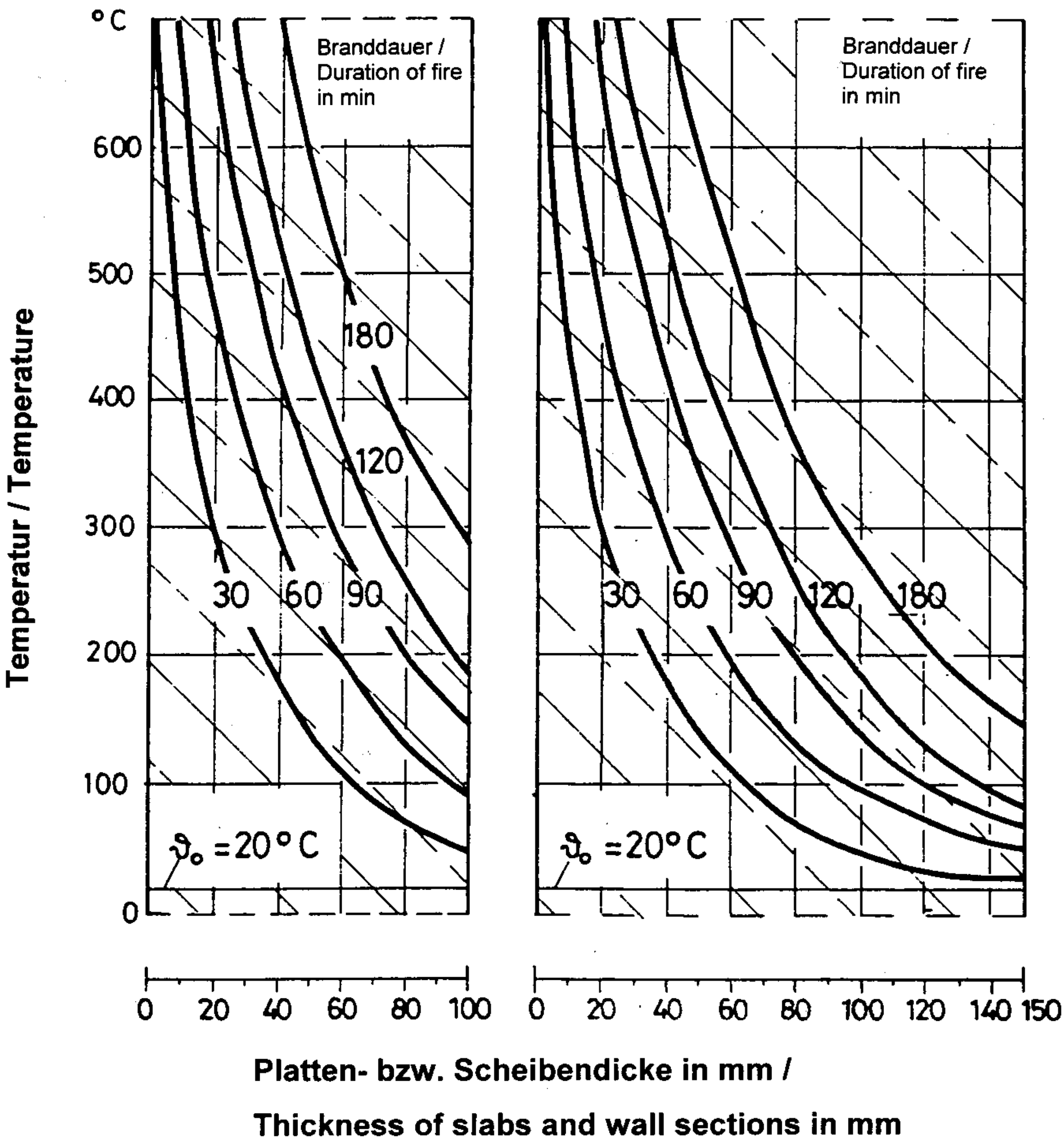

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Fig. 3 : Graphical presentation of test results obtained with Hilti HIT-HY 150 injection adhesive using reinforcing bars of steel grade BSt 500 S as a function of the actual bond stress

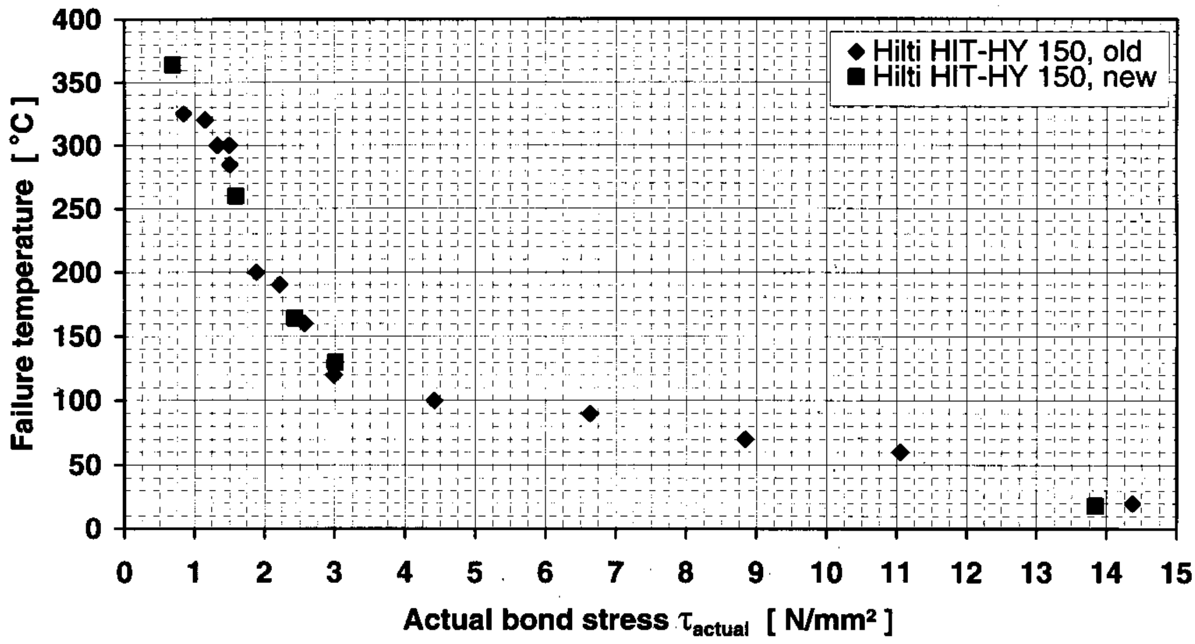

Fig. 4 : Design curve for Hilti HIT-HY 150 injection adhesive, based on the test results, as a function of failure temperature and critical, temperature-dependent bond stress, $\tau_{crit,T}$

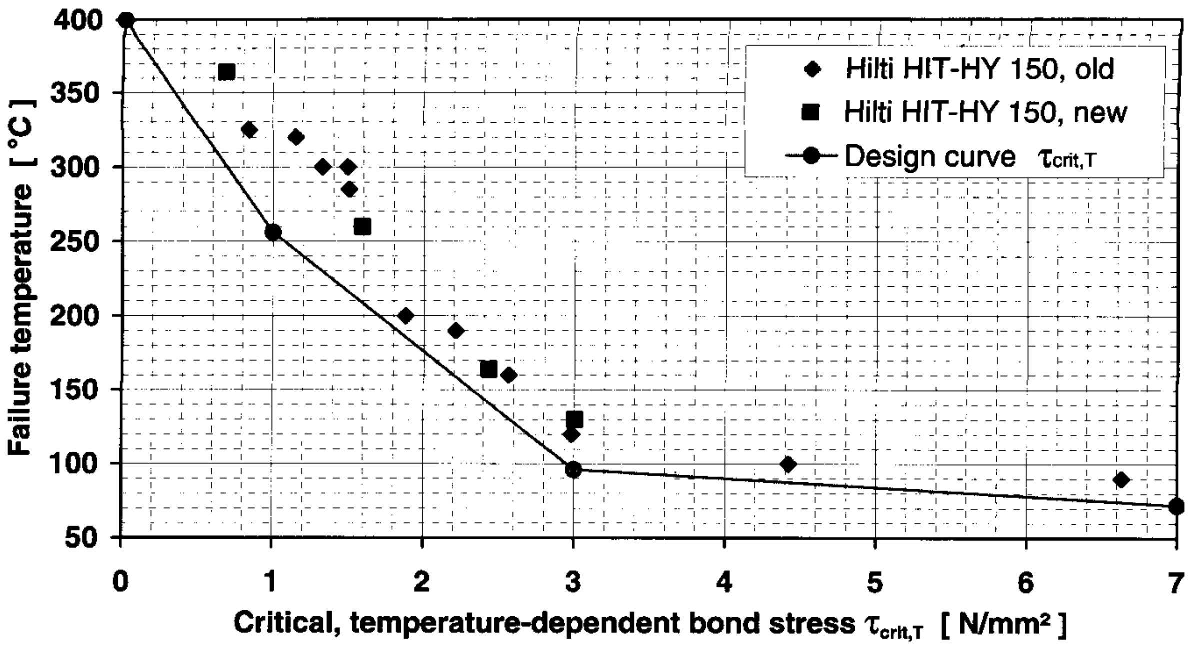

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Table 2 : Critical, temperature-dependent bond stress, $\tau_{crit,T}$, in relation to fire resistance times of 30 to 180 minutes and the required minimum concrete coverage, c

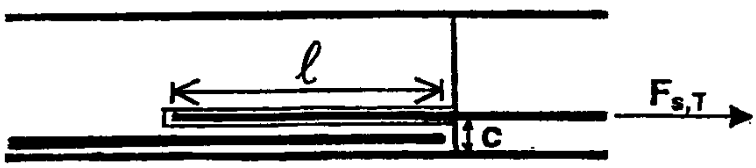
<table>
<tr><th rowspan="2">Concrete Coverage
c
[mm]</th><th colspan="5">Critical, temperature-dependent bond stress $\tau_{crit,T}$
for a fire resistance class of</th></tr>
<tr><th>F30
[N/mm^2]</th><th>F60
[N/mm^2]</th><th>F90
[N/mm^2]</th><th>F120
[N/mm^2]</th><th>F180
[N/mm^2]</th></tr>
<tr><td>20</td><td>0,7</td><td>0</td><td rowspan="3">0</td><td rowspan="4">0</td><td rowspan="6">0</td></tr>
<tr><td>30</td><td>1,4</td><td>0,2</td></tr>
<tr><td>40</td><td>1,9</td><td>0,7</td></tr>
<tr><td>50</td><td>2,4</td><td>1,2</td><td>0,4</td></tr>
<tr><td>60</td><td>2,8</td><td>1,7</td><td>0,7</td><td>0,3</td></tr>
<tr><td>70</td><td>4,9</td><td>2,2</td><td>1,2</td><td>0,7</td></tr>
<tr><td>80</td><td rowspan="17">7,0</td><td>2,5</td><td>1,7</td><td>1,0</td><td>0,2</td></tr>
<tr><td>90</td><td>2,8</td><td>2,0</td><td>1,5</td><td>0,5</td></tr>
<tr><td>100</td><td>4,0</td><td>2,3</td><td>1,9</td><td>0,7</td></tr>
<tr><td>110</td><td>4,5</td><td>2,7</td><td>2,3</td><td>1,2</td></tr>
<tr><td>120</td><td>6,5</td><td>2,9</td><td>2,6</td><td>1,6</td></tr>
<tr><td>130</td><td rowspan="12">7,0</td><td>4,0</td><td>2,8</td><td>1,9</td></tr>
<tr><td>140</td><td>6,5</td><td>3,0</td><td>2,2</td></tr>
<tr><td>150</td><td rowspan="10">7,0</td><td>4,5</td><td>2,3</td></tr>
<tr><td>160</td><td>6,5</td><td>2,5</td></tr>
<tr><td>170</td><td rowspan="8">7,0</td><td>2,6</td></tr>
<tr><td>180</td><td>2,7</td></tr>
<tr><td>190</td><td>2,8</td></tr>
<tr><td>200</td><td>2,9</td></tr>
<tr><td>210</td><td>3,0</td></tr>
<tr><td>220</td><td>4,5</td></tr>
<tr><td>230</td><td>6,5</td></tr>
<tr><td>240</td><td>7,0</td></tr>
</table>

...

3.3 Overlap joint

Verification of the suitability of overlap joints exposed to temperature must be provided according to the following formula. Fig. 5 below shows, schematically, the rebar connection version "OVERLAP JOINT".

Fig. 5 : Schematic depiction of rebar connection version "OVERLAP JOINT"



$$F_{s,T} \leq l \cdot d_s \cdot \pi \cdot \tau_{crit,T}$$

Whereby :

$F_{s,T}$ force in the reinforcing bar subjected to fire exposure

l length of overlap joint

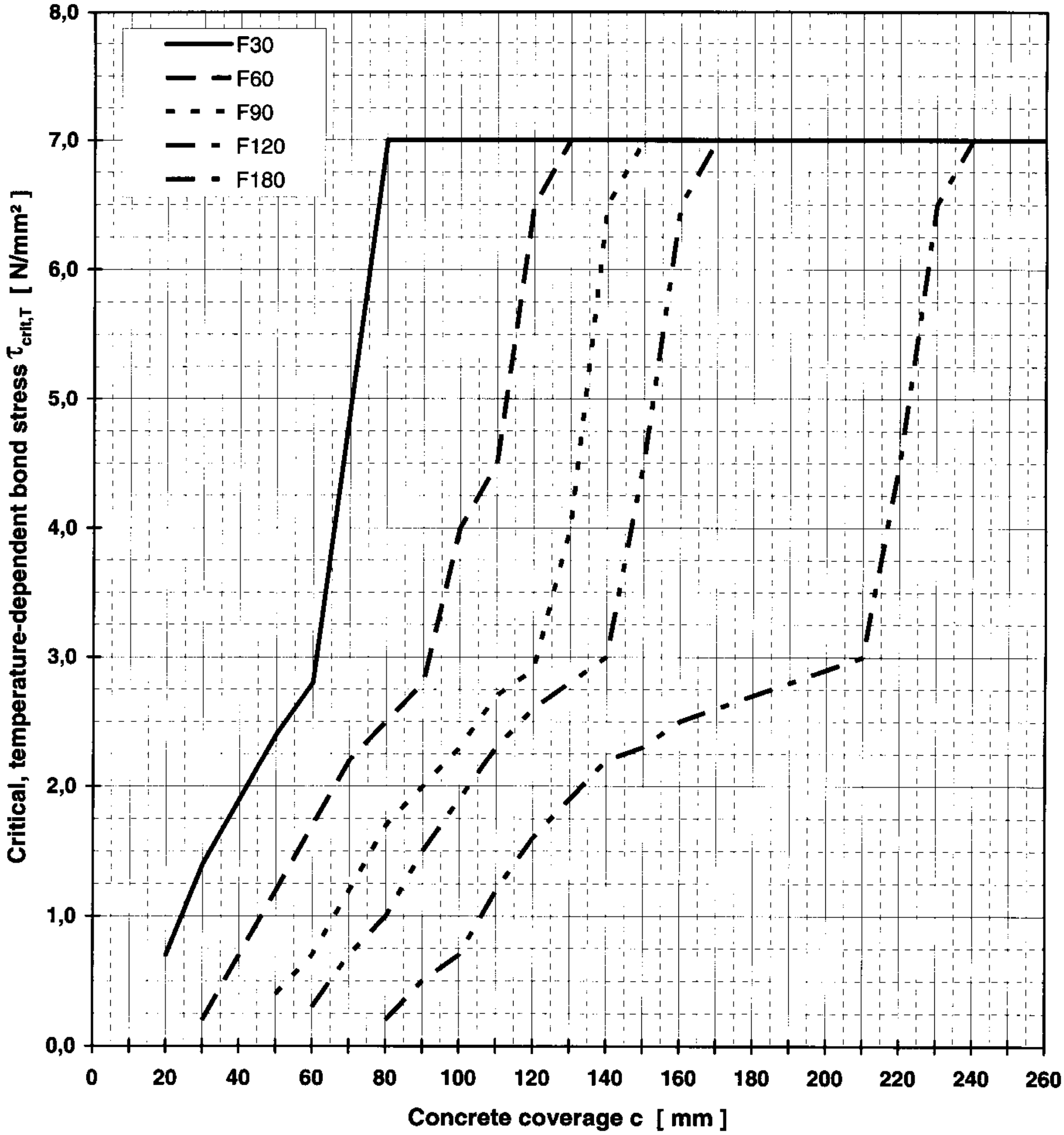
d_s nominal diameter of the reinforcing bar

$\tau_{crit,T}$ critical, temperature-dependent bond stress as per table 2 and figure 6 based on consideration of the concrete coverage, c

Evaluations of the critical, temperature-dependent bond stress, $\tau_{crit,T}$, in relation to the concrete coverage, c, and the respective, stipulated fire resistance time of rebar connection version "OVERLAP JOINT" are shown in table 2 (see page 9) and fig. 6 (see page 11). In this respect, the length of overlap joint may not exceed 80 times the nominal rebar diameter, d_s, when the joint is exposed to fire.

...

Fig. 6 : Graphical evaluation for rebar connection version "OVERLAP JOINT" made with reinforcing steel of BSt 500 S grade, 8 to 25 mm in diameter, and Hilti HIT-HY 150 injection adhesive as a function of the concrete coverage, c, and the critical, temperature-dependent bond stress, $\tau_{crit,T}$, for a fire resistance time of 30 to 180 minutes



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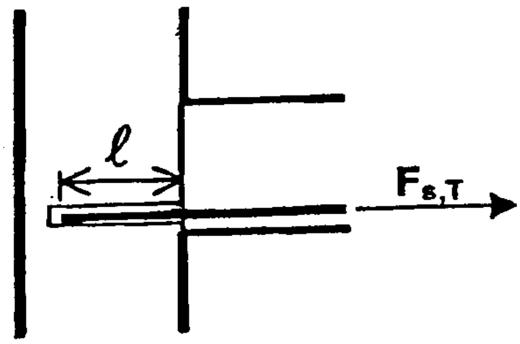
3.4 Anchored rebar

Verification of the suitability of anchored rebars subjected to temperature must be calculated using the following formula. Fig. 7 below shows, schematically, the rebar connection version "ANCHORED REBAR".

Fig. 7 : Schematic depiction of rebar connection version "ANCHORED REBAR"



$$F_{s,T} \leq A_s \bullet \sigma_s$$

Whereby :

$F_{s,T}$ force in the reinforcing bar subjected to fire exposure

A_s cross-sectional area of the reinforcing bar

σ_s stress in steel transferable to concrete joint through the injection adhesive in relation to the anchorage depth, l, of the reinforcing bar and the fire resistance times as per figures 8 to 12

Verification of the design of connection version "ANCHORED REBAR" is provided on basis of integration of the critical temperature-dependent bond stress, $\tau_{crit,T}$, in relation to the rebar anchorage depth. This is given in figs. 8 to 12 (see pages 13 to 17) as a function of the maximum steel stress, σ_s, in relation to the anchorage depth, l, for bar diameters of 8 to 25 mm and a fire resistance time of 30 to 180 minutes.

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Fig. 8 : **Graphical evaluation for rebar connection version "ANCHORED REBAR" made with reinforcing steel of BSt 500 S grade, 8 to 25 mm in diameter, and Hilti HIT-HY 150 injection adhesive as a function of the anchorage depth, l, and the stress in steel, σ_s, for a fire resistance time of 30 minutes**

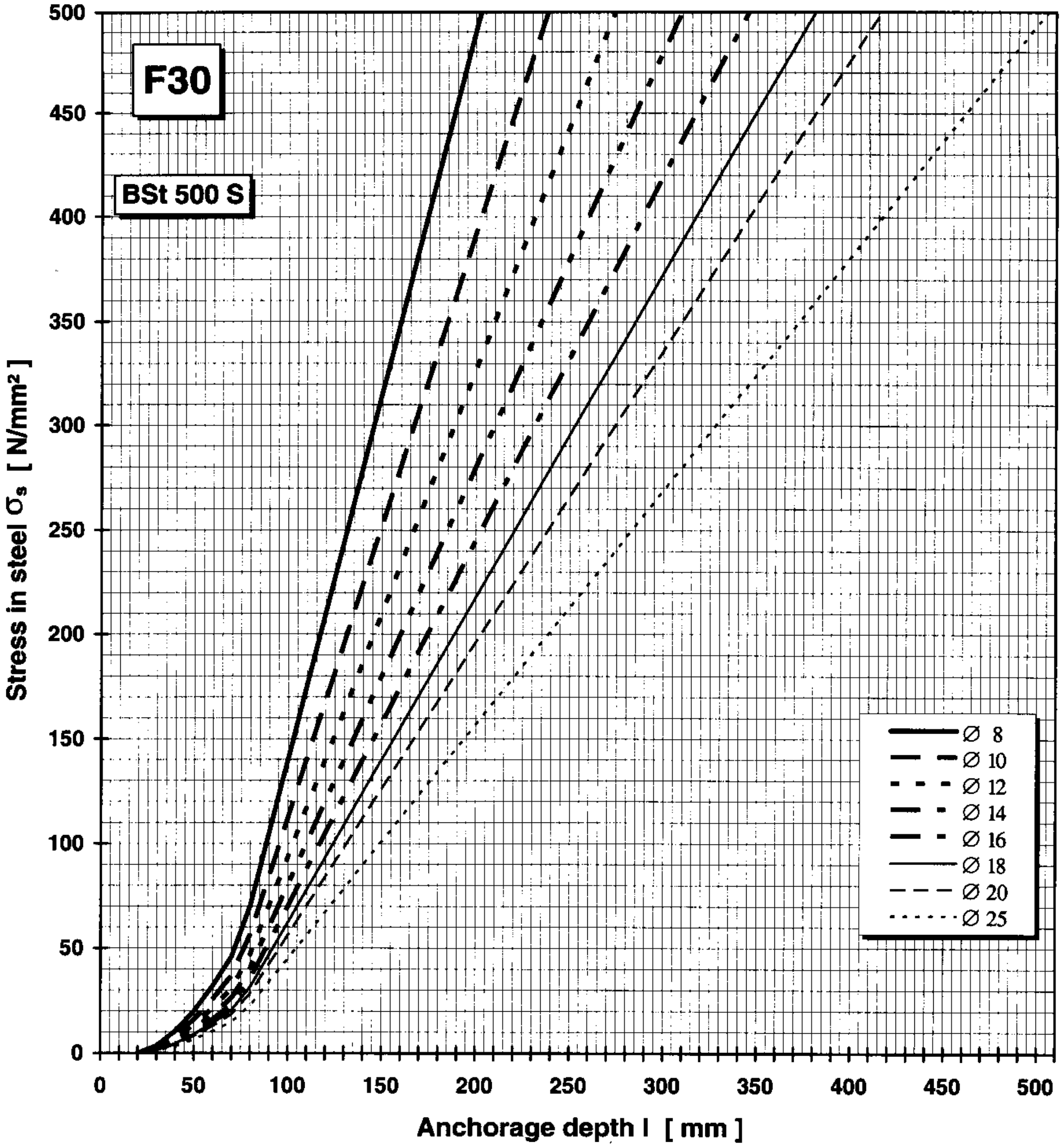

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Fig. 9 : **Graphical evaluation for rebar connection version "ANCHORED REBAR" made with reinforcing steel of BSt 500 S grade, 8 to 25 mm in diameter, and Hilti HIT-HY 150 injection adhesive as a function of the anchorage depth, l, and the stress in steel, σ_s, for a fire resistance time of 60 minutes**

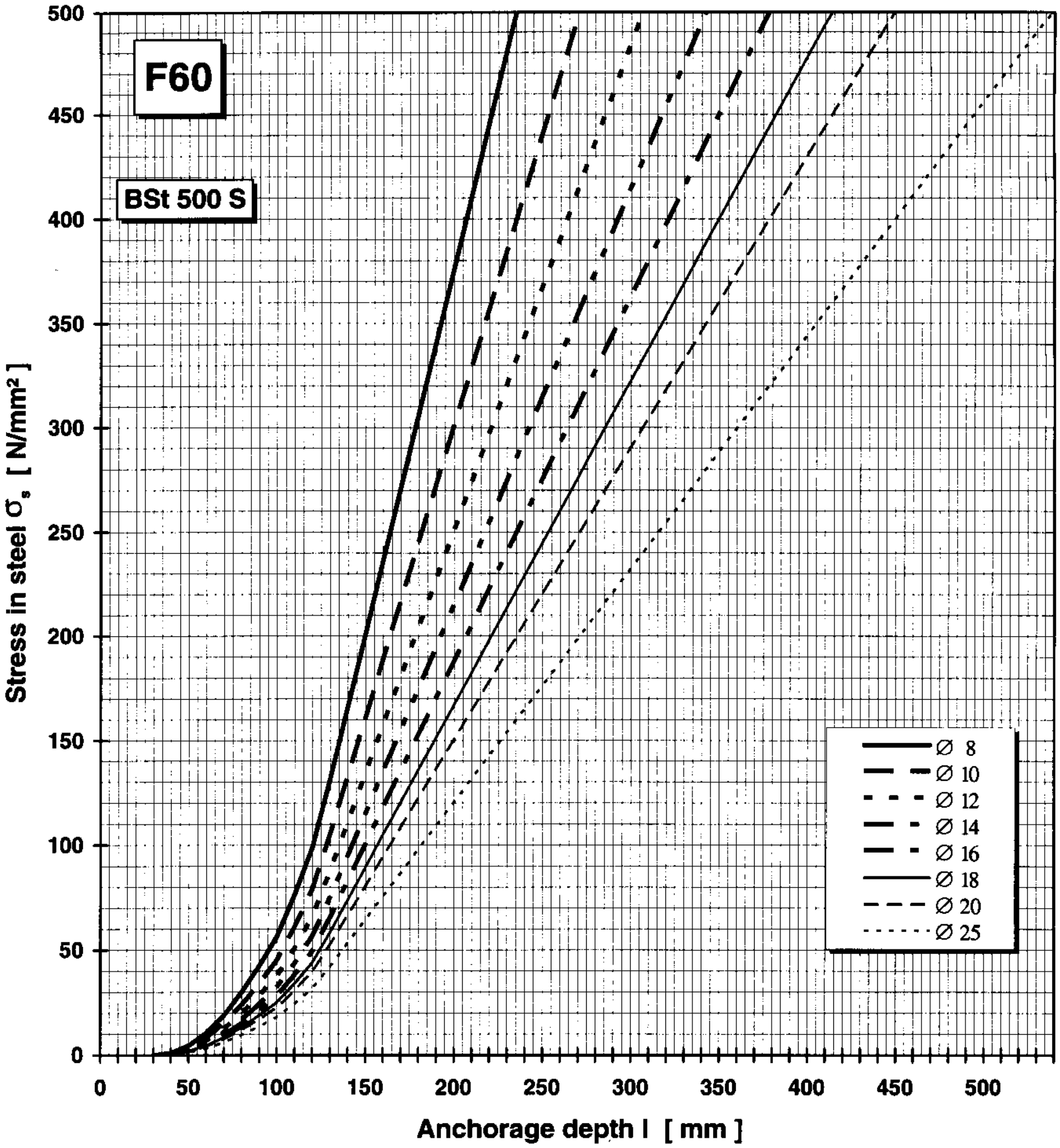

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Fig. 10 : **Graphical evaluation for rebar connection version "ANCHORED REBAR" made with reinforcing steel of BSt 500 S grade, 8 to 25 mm in diameter, and Hilti HIT-HY 150 injection adhesive as a function of the anchorage depth, l, and the stress in steel, σ_s, for a fire resistance time of 90 minutes**

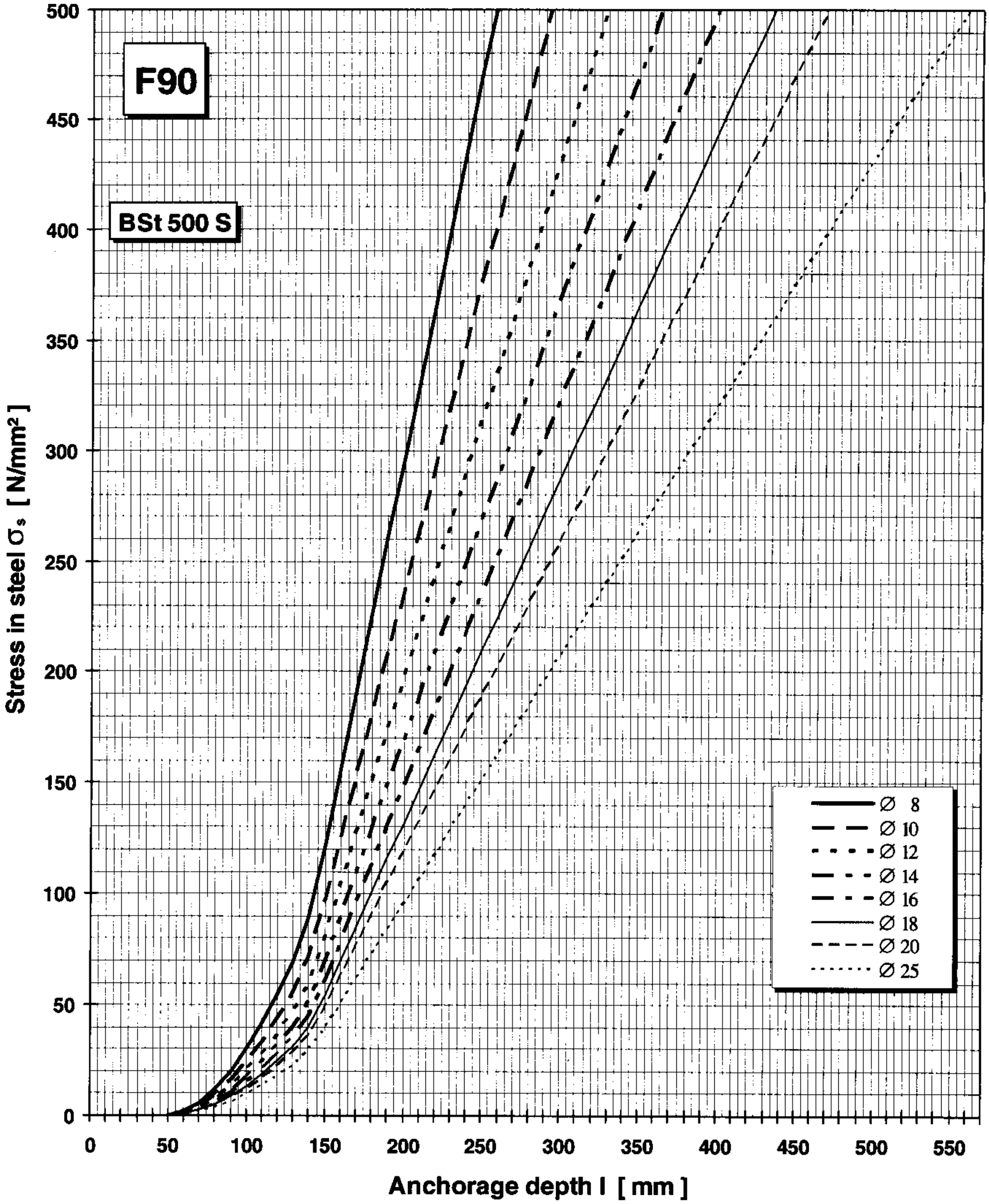

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Fig. 11 : **Graphical evaluation for rebar connection version "ANCHORED REBAR" made with reinforcing steel of BSt 500 S grade, 8 to 25 mm in diameter, and Hilti HIT-HY 150 injection adhesive as a function of the anchorage depth, l, and the stress in steel, σ_s, for a fire resistance time of 120 minutes**

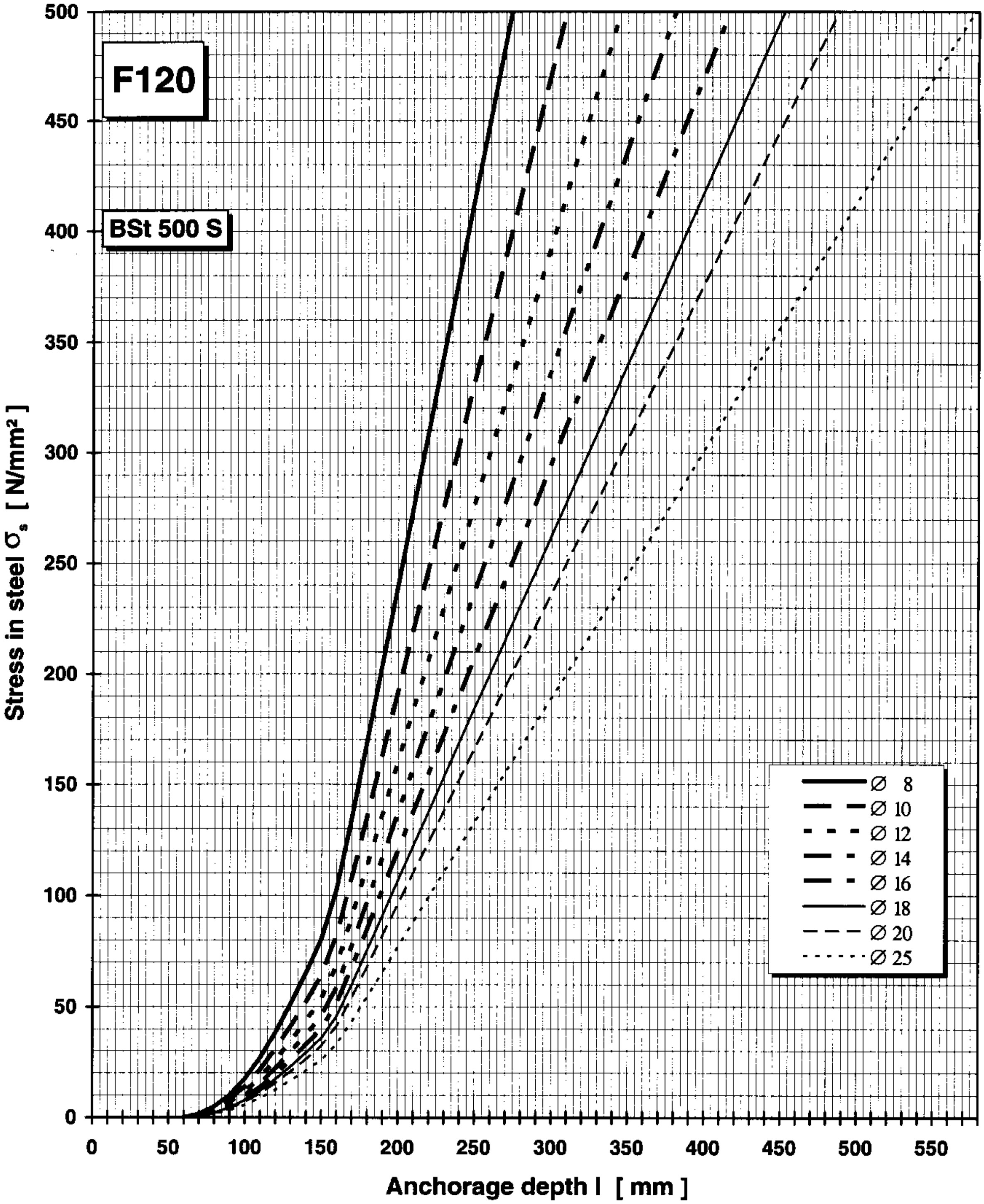

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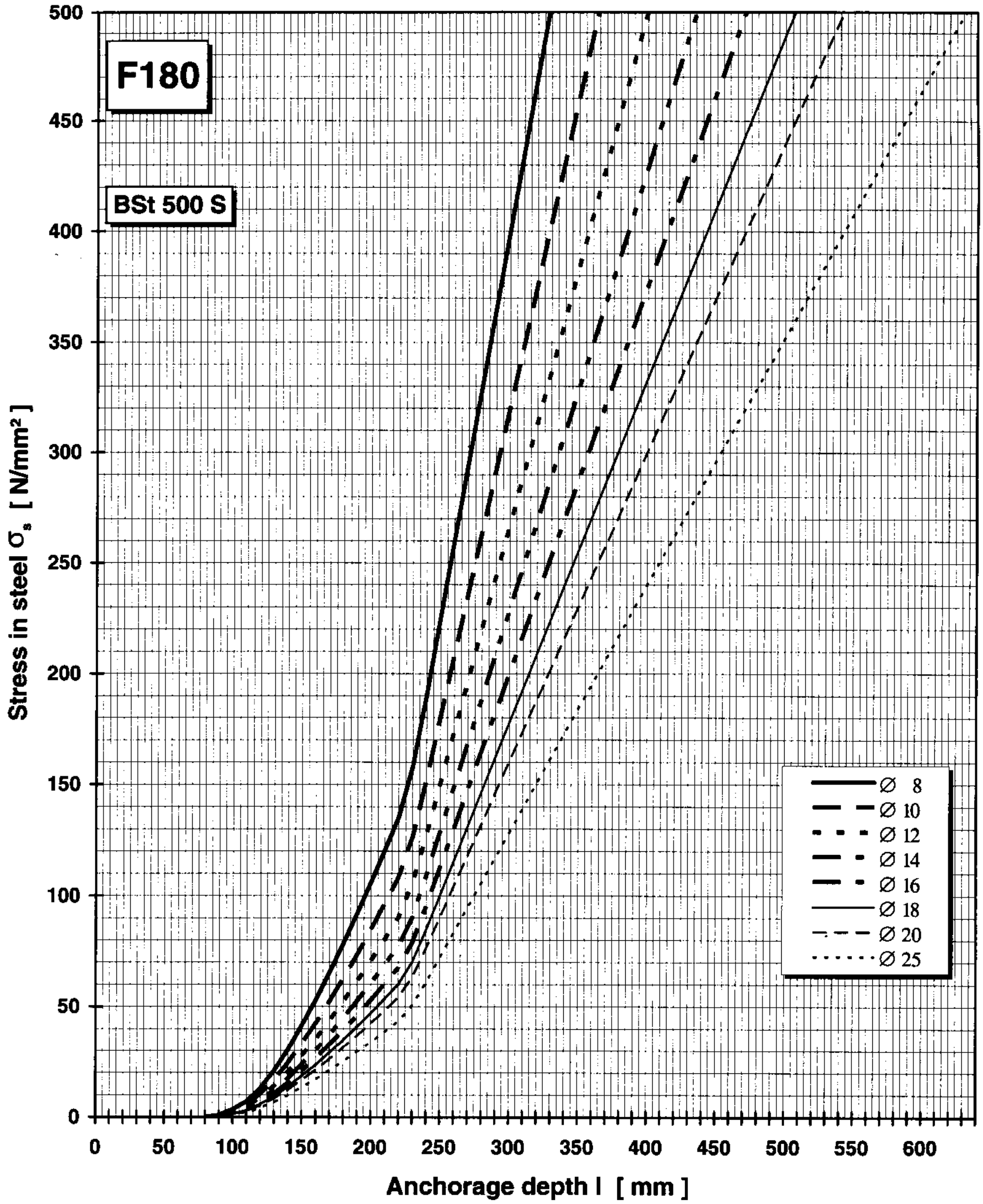
Fig 12 : **Graphical evaluation for rebar connection version "ANCHORED REBAR" made with reinforcing steel of BSt 500 S grade, 8 to 25 mm in diameter, and Hilti HIT-HY 150 injection adhesive as a function of the anchorage depth, l, and the stress in steel, σ_s, for a fire resistance time of 180 minutes**



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4 Conclusions

In the period from calendar week 27, 1994, to calendar week 41, 1998, 22 specimens made with Hilti HIT-HY 150 injection adhesive and rebar sections of the steel grade BSt 500 S, 12 mm in diameter, set in concrete cylinders of the grade ≥ C 20/25, were tested on their high temperature behaviour in accordance with ISO 834 and subjected to pure tensile loading to determine the pull-out behaviour.

By means of the test results obtained with Hilti HIT-HY 150 injection adhesive system, it was possible to calculate on the safe side critical, temperature-dependent bond stresses, $\tau_{crit,T}$, in relation to the respective concrete coverage, c, for a fire resistance time of 30 to 180 minutes. These, among other aspects, provided the basis for the requested technical design concept for the application of rebar connections suitable for fire protection.

Based on the temperature-dependent bond stress, $\tau_{crit,T}$, rulings have been provided for the required concrete coverage, c, and rebar connection version **"overlap joint"** respectively for the required anchorage depth, l, and connection version **"anchored rebar"** in the technical design concept for Hilti HIT-HY 150 injection system in relation to the respective fire resistance class as defined in sections 3.3 and 3.4.

Verification of the loading capacity of adhesive bonded overlap joints or anchored rebars exposed to fire in accordance with ISO 834 must be provided at the same time as verification of the serviceability state as per DIN 1045 and EC 2. Here, the larger calculated value concerning the overlap joint length or the rebar anchorage depth is decisive.

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5 Special notes

5.1 This expert assessment applies only to the Hilti HIT-HY 150 injection adhesive (current standard formulation), when taking into account the general conditions given in the client's technical data sheets for the rebar connection versions **"overlap joint"** and **"anchored rebar"**.

5.2 The evaluation of the Hilti HIT-HY 150 injection adhesive (standard formulation) applies only in connection with reinforced-concrete slabs or wall sections which are exposed to fire on one side and can be classified in at least a fire resistance class corresponding to the fire resistance time of the Hilti HIT-HY 150 injection adhesive.

5.3 This expert assessment is only for presentation to the Deutsches Institut für Bautechnik, Berlin, for the application for a general approval.

Director
On behalf

Dipl.-Ing. Nause
Deputy Department Manager

See page 20 for a list of annexes

List of annexes

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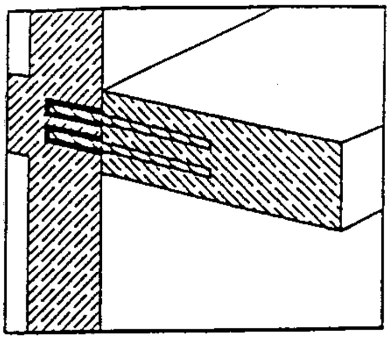
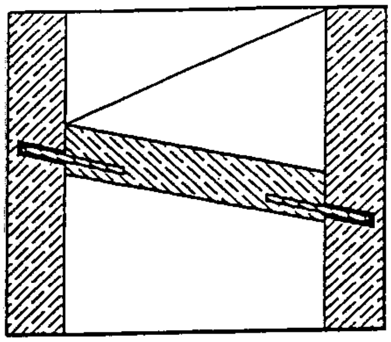
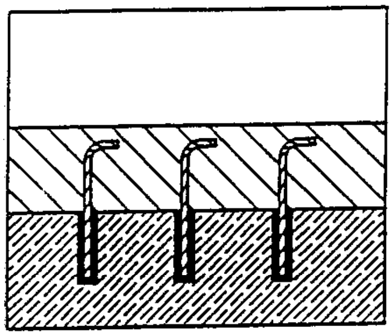


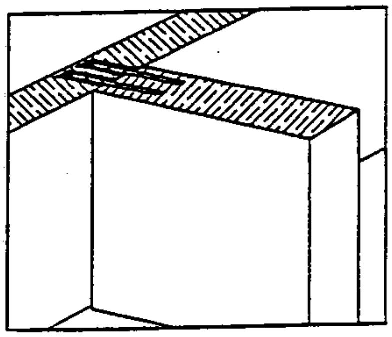
Balcony connection



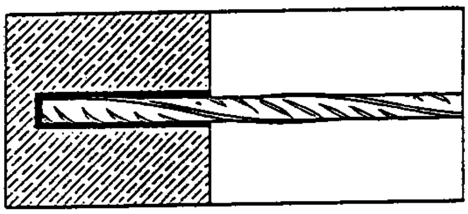
Floor connection



Concrete overlay connection



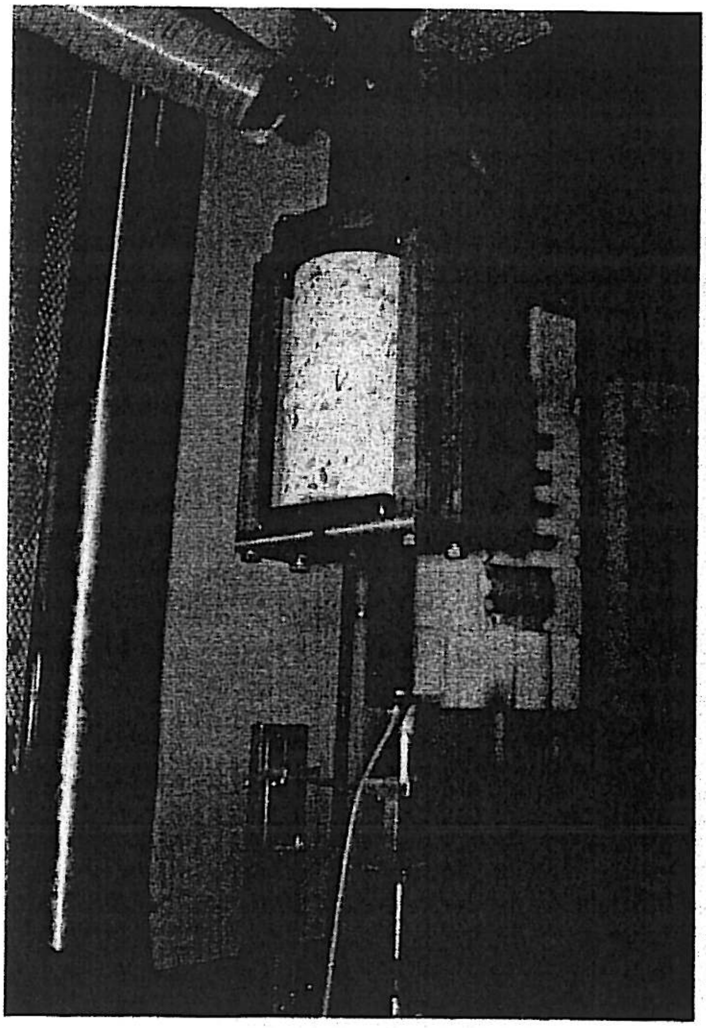
Wall connection



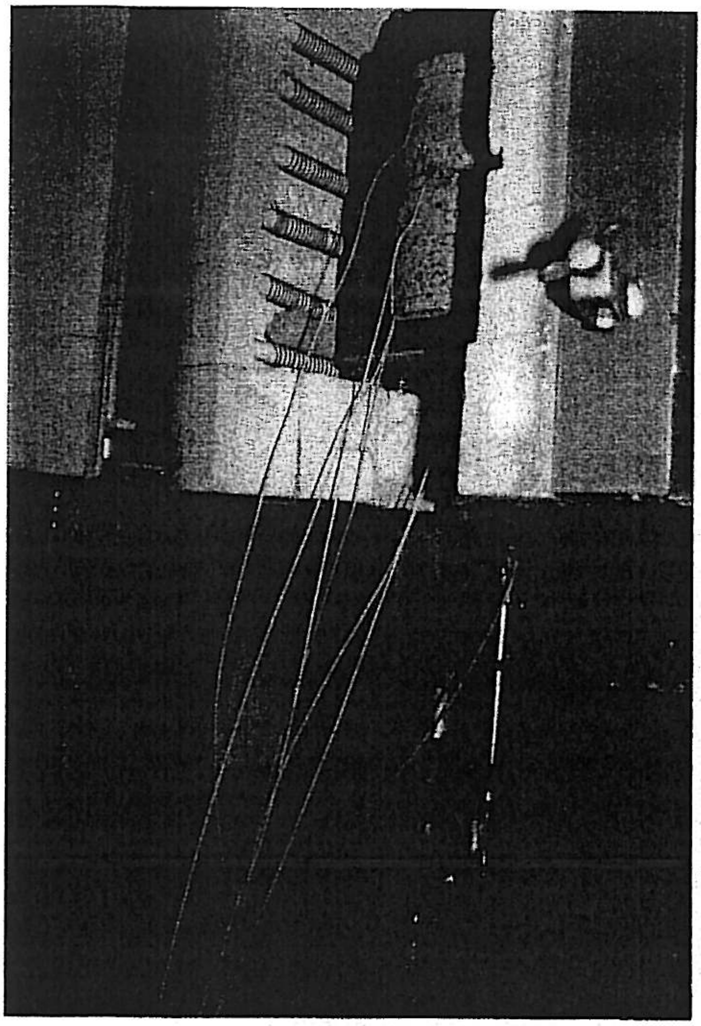
- Fastening of rebars
- As cast in
- High loads
- Design based on steel yield strength
- Design as per Eurocode 2
- Concrete and hard natural stone
- High level of safety / reliability
- Minimal displacement
- Small diameter of drilled hole
- Containing no styrene

- Automatic opening
- Reliable mixing
- Accurate dispensing
- Application friendly
- A coordinated complete system

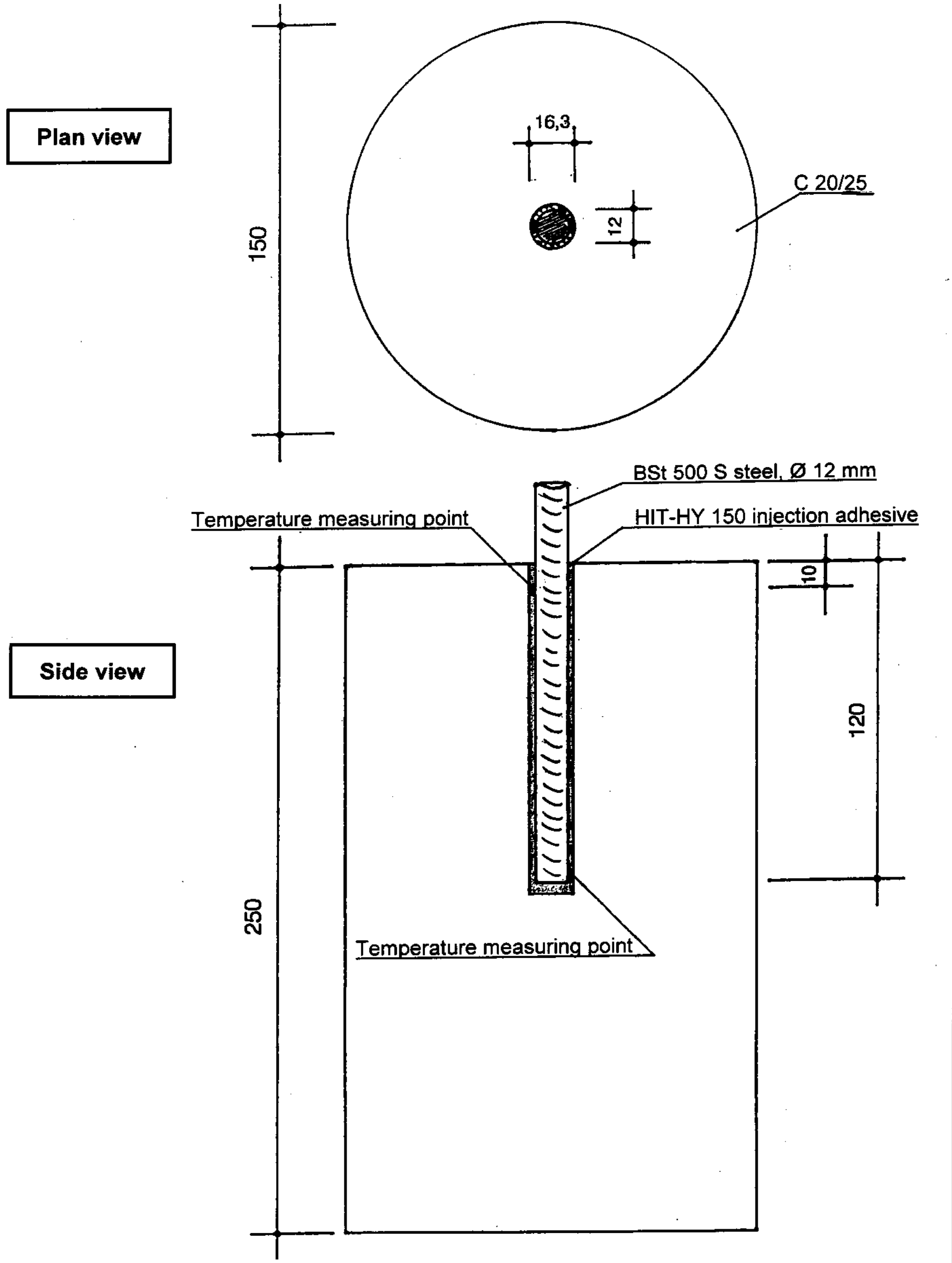
Fields of application and construction examples for the use of Hilti HIT-HY 150 injection system	Annex 1 of Expert Assessment No. 3162/6989 -Nau- dated July 16, 1999
Materialprüfanstalt für das Bauwesen Institut für Baustoffe, Massivbau und Brandschutz Technische Universität Braunschweig	



Konstruktiver Aufbau der Prüfeinrichtung	Anlage 2 zur Gutachtlichen Stellungnahme Nr. 3162/6989 -Nau- vom 16.07.1999
Materialprüfanstalt für das Bauwesen Institut für Baustoffe, Massivbau und Brandschutz Technische Universität Braunschweig	



Konstruktiver Aufbau der Prüfeinrichtung	Anlage 3 zur Gutachtlichen Stellungnahme Nr. 3162/6989 -Nau- vom 16.07.1999
Materialprüfanstalt für das Bauwesen Institut für Baustoffe, Massivbau und Brandschutz Technische Universität Braunschweig	



Test arrangement of rebars set with Hilti HIT-HY 150 injection system (all dimensions in mm)	Annex 4 of Expert Assessment No. 3162/6989 -Nau- dated July 16, 1999
Materialprüfanstalt für das Bauwesen Institut für Baustoffe, Massivbau und Brandschutz Technische Universität Braunschweig	

Materialprüfanstalt für das Bauwesen · Beethovenstr. 52 · 38106 Braunschweig

Hilti Entwicklungsgesellschaft mbH
Attention of Mr. M. Hartmann / DETA
Hiltistraße 6

D – 86 916 KAUFERING

Your reference	Your letter dated	Our reference	Person responsible	Direct dialling no.	Braunschweig, date
DETAhm		120/02 -Nau-	RR Dipl.-Ing. Nause	-5475	August 6, 2002

Expert Assessment no. 3162/6989 -Nau- dated July 16, 1999 on a technical design concept for rebar connections suitable for fire resistance using reinforcing steel bars of BSt 500 S grade, 8 to 25 mm in diameter, and Hilti HIT-HY 150 injection adhesive

Here : Supplementary letter about evaluation of the test results for application according to British Standard BS 8110 : 1 - 1997 and Singapore Standard CP-65 : 1999

7 Annexes

Dear Mr. Hartmann,

according to the application, a passive fire resistance evaluation of rebar connections made with reinforcing steel bars and Hilti HIT-HY 150 injection adhesive was carried out during high-temperature tests in keeping with ISO 834 using small specimens (concrete cylinders) loaded in pure tension to determine the thermo-mechanical properties and the rebar pull-out behaviour.

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für das Bauwesen
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D-38106 Braunschweig

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Swift-Code: NOLADE 2H
USt.-ID-Nr. MPA-DE 183500654

Deutscher Akkreditierungs Rat

The tested Hilti HIT-HY 150 injection system is a means of making fastenings without expansion forces when set in normal concrete with quarzitic aggregates and subjected primarily to a static (dead) load.

The Hilti HIT-HY 150 injection system is an anchoring system with a working principle based on utilisation of the bond between steel, the two-component injection adhesive and concrete. The Hilti HIT-HY 150 injection system consists of a ready-to-use, prepared two-component injection adhesive with combined organic and inorganic binders, i.e. a hybrid system, that is contained in a dual foil pack whose contents are injected into a drilled hole through an interchangeable, static forced mixer by a dispenser. The Hilti HIT-HY 150 injection adhesive is a binder system that, on the one hand, is based on a urethane methacrylate resin, and, on the other hand, on cement. Steel bar material of the grade BSt 500 S with a diameter of 12 mm was used as the reinforcing steel. Technical data sheets from the applicant provide a ruling on setting and loading the fastenings made with the Hilti HIT-HY 150 injection system.

The rebars were set with the Hilti HIT-HY 150 injection system in accordance with the applicant's technical data sheets, while using the pertaining setting tools specified in them, i.e. rotary hammer, drill bit, dispenser and static forced mixer.

The tests were carried out in an electrically heated, servo-hydraulic, high-temperature test furnace. In the middle of a base surface of each concrete cylinder, a hole was drilled to a depth approximately 120 mm and with a nominal diameter, d, of 14 or 16 mm. After the holes had been cleaned, the rebars were set at an anchorage depth, l, of 120 mm using Hilti HIT-HY 150. Prior to setting each rebars, thermocouples were fastened to it in such a way that during the test the temperature in the injection adhesive at a depth about 10 mm below the concrete surface and on the lower end of the rebar at the bottom of the hole could be measured. The press cylinder of the test rig transferred the load centrally to the reinforcing bar.

Thermocouples fastened to the circumference of the concrete cylinders increased and measured the temperatures in the test rig. During the tests, the displacement of the rebars relative to the concrete surface was continuously plotted by a measuring device outside the rig.

On basis of the test results, [1] and other testing experience concerning the heating-up behaviour of normal concrete with quarzitic aggregates, and keeping on the safe side, critical temperature-dependent bond stresses, $\tau_{crit,T}$, in relation to the respective concrete coverage, c, can be given in table 1 (see annex 2) for a fire resistance time of 30 to 240 minutes.

...

From these, the intention was to develop a technical fire resistance design concept for the applications depicted in following figures 1 and 2 as well as figures 3 and 4 (see annex 1) :

- OVERLAP JOINT (i.e. bar parallel to the concrete surface)

  and

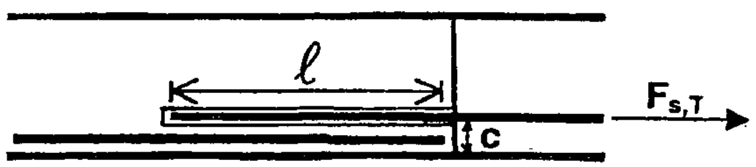
- ANCHORING (i.e. bar vertical to the concrete surface)

for rebar connections made in reinforced concrete slabs or discs exposed to fire on one side.

Verification of the loading capacity of the bonded-in overlap joints and anchored rebars exposed to fire in accordance with ISO 834 has to be provided at the same time as verification of the serviceability state according to British Standard BS 8110 : 1 - 1997 and Singapore Standard CP-65 : 1999, where the larger of the two values is decisive for the overlap joint length respectively the rebar anchorage depth.

The following formula should be used to verify the design of an overlap joint when exposed to fire. In fig. 1 below, the overlap joint is been shown schematically.

Fig. 1 : Schematic depiction of the rebar connection version "OVERLAP JOINT"



$$F_{s,T} \leq l \cdot d_s \cdot \pi \cdot \tau_{crit,T}$$

Where:

$F_{s,T}$ Force in rebar when exposed to fire
l Overlapping length of joint
d_s Nominal rebar diameter
$\tau_{crit,T}$ Critical temperature-dependent bond stress as per table 1 allowing for concrete coverage, c

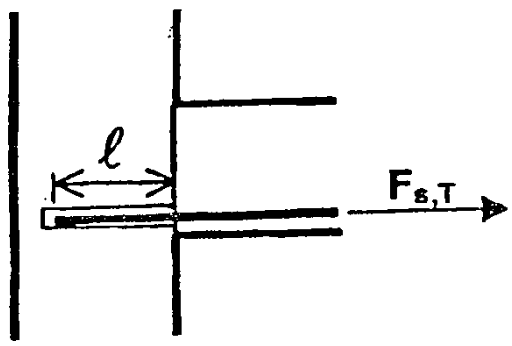
...

The evaluation for the critical, temperature-dependent bond stresses, $\tau_{crit,T}$, in relation to the concrete coverage, c, and the respective, stipulated fire resistance time of the connection version "OVERLAP JOINT" is given in table 1 (see annex 2) of this supplementary letter, where the length of the overlap joint when exposed to fire may not exceed 80 times the nominal rebar diameter, d_s. This evaluation only depends on the thermo-mechanical properties of the injection adhesive and the concrete coverage, c.

The concrete coverage that is required for a fire resistance time of 30 to 240 minutes may get partly replaced by revetments or plasters suitable for fire protection and must guarantee altogether the required fire resistance time.

Verification of the design of an anchored rebar exposed to fire must be calculated using the following formula. The connection version "ANCHORED REBAR" is shown schematically in fig. 2 below.

Fig. 2 : Schematic depiction of the rebar connection version "ANCHORED REBAR"



$$F_{s,T} \leq A_s \bullet \sigma_s$$

Where:

$F_{s,T}$ Force in rebar when exposed to fire

A_s Cross-sectional area of rebar

σ_s Stress in steel transferable to concrete joint through injection adhesive in relation to anchorage depth, l, of rebar and fire resistance time

...

Verification of the design of the connection version "ANCHORED REBAR" is provided on the basis of integration of the critical temperature-dependent bond stress, $\tau_{crit,T}$, in relation to rebar anchorage depth. This is given for the application according to British Standard BS 8110 : 1 - 1997 in tables 3 and 4 (see annexes 4 and 5) and according to Singapore Standard CP-65 : 1999 in tables 5 and 6 (see annexes 6 and 7) as the maximum force of the rebars in relation to anchorage depth, l, for bar diameters of 8 to 25 mm and a fire resistance time of 30 to 240 minutes.

The safety factors specified in British and Singapore Standard as well as the yielding point of the reinforcing steel and the necessary bar diameters, which had been used to calculate the values for connection version ANCHORING, are given in table 2 (see annex 3) of this supplementary letter.

This supplementary letter is valid **only** when read in conjunction with the above-mentioned expert assessment.

The validity of this supplementary letter ends with the validity of the above-mentioned assessment.

We hope this information will be of assistance to you and remain

Yours faithfully

The Director
On behalf

RR Dipl.-Ing. Nause
Deputy Department Manager

Reference literature

[1] Beton-Brandschutz-Handbuch
(Passive fire prevention manual of concrete),
Prof. Dr.-Ing. Dr.-Ing. E.h. K. Kordina and
Dr.-Ing. C. Meyer-Ottens, issue 1981

...

Fig. 3 : **Schematic depiction of rebar connection version "OVERLAP JOINT"**

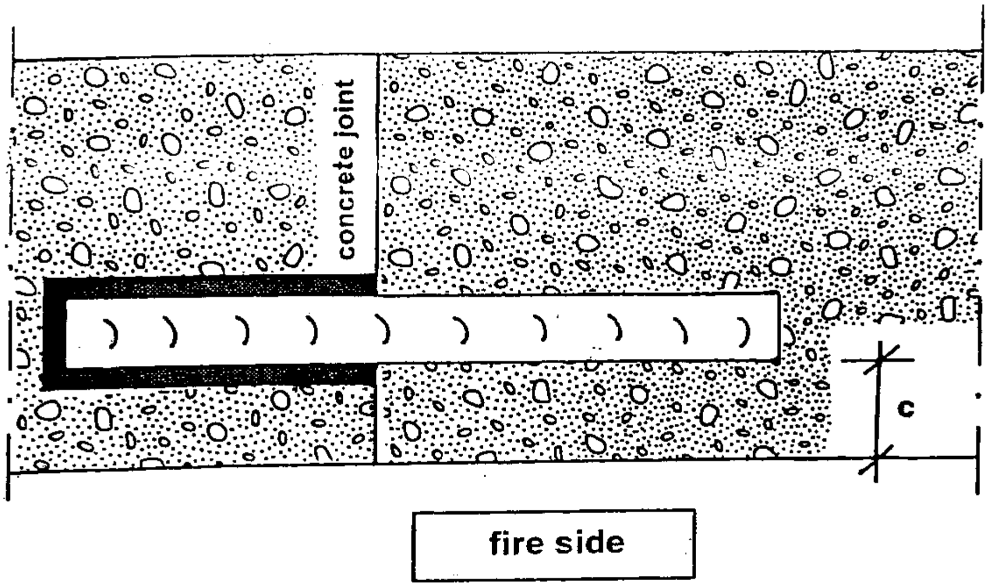


Fig. 4 : **Schematic depiction of rebar connection version "ANCHORED REBAR"**

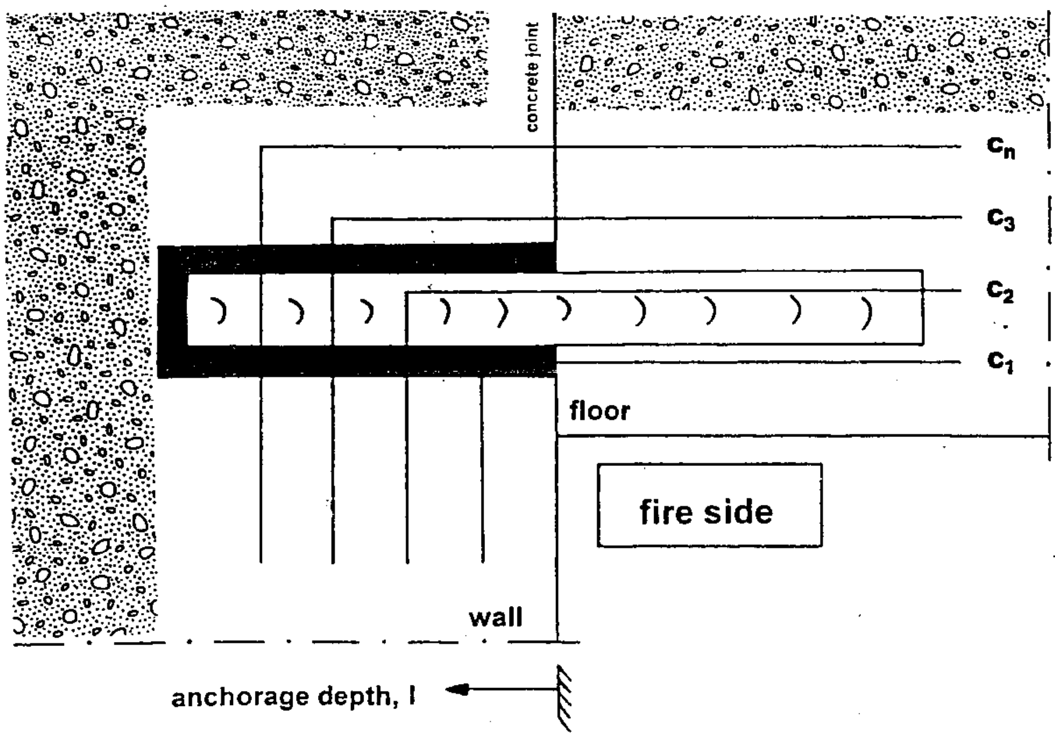


Table 1 : Critical temperature-dependent bond stress, $\tau_{crit,T}$, concerning "OVERLAP JOINT" in relation to a fire resistance time of 30 to 240 minutes and the required minimum concrete coverage, c

<table>
<tr><th rowspan="2">Concrete coverage</th><th colspan="6">Critical temperature dependend bond stress $\tau_{crit,T}$ of
Hilti HIT-HY 150
for fire resistance class</th></tr>
<tr><th>F30</th><th>F60</th><th>F90</th><th>F120</th><th>F180</th><th>F240</th></tr>
<tr><th>c
[mm]</th><th>[N/mm²]</th><th>[N/mm²]</th><th>[N/mm²]</th><th>[N/mm²]</th><th>[N/mm²]</th><th>[N/mm²]</th></tr>
<tr><td>20</td><td>0,7</td><td>0</td><td rowspan="3">0</td><td rowspan="4">0</td><td rowspan="6">0</td><td rowspan="8">0</td></tr>
<tr><td>30</td><td>1,4</td><td>0,2</td></tr>
<tr><td>40</td><td>1,9</td><td>0,7</td></tr>
<tr><td>50</td><td>2,4</td><td>1,2</td><td>0,4</td></tr>
<tr><td>60</td><td>2,8</td><td>1,7</td><td>0,7</td><td>0,3</td></tr>
<tr><td>70</td><td>4,9</td><td>2,2</td><td>1,2</td><td>0,7</td></tr>
<tr><td>80</td><td rowspan="17">7,0</td><td>2,5</td><td>1,7</td><td>1,0</td><td>0,2</td></tr>
<tr><td>90</td><td>2,8</td><td>2,0</td><td>1,5</td><td>0,5</td></tr>
<tr><td>100</td><td>4,0</td><td>2,3</td><td>1,9</td><td>0,7</td><td>0,3</td></tr>
<tr><td>110</td><td>4,5</td><td>2,7</td><td>2,3</td><td>1,2</td><td>0,6</td></tr>
<tr><td>120</td><td>6,5</td><td>2,9</td><td>2,6</td><td>1,6</td><td>0,8</td></tr>
<tr><td>130</td><td rowspan="12">7,0</td><td>4,0</td><td>2,8</td><td>1,9</td><td>1,1</td></tr>
<tr><td>140</td><td>6,5</td><td>3,0</td><td>2,2</td><td>1,4</td></tr>
<tr><td>150</td><td rowspan="10">7,0</td><td>4,5</td><td>2,3</td><td>1,7</td></tr>
<tr><td>160</td><td>6,5</td><td>2,5</td><td>2,0</td></tr>
<tr><td>170</td><td rowspan="8">7,0</td><td>2,6</td><td>2,2</td></tr>
<tr><td>180</td><td>2,7</td><td>2,4</td></tr>
<tr><td>190</td><td>2,8</td><td>2,6</td></tr>
<tr><td>200</td><td>2,9</td><td>2,8</td></tr>
<tr><td>210</td><td>3,0</td><td>3,0</td></tr>
<tr><td>220</td><td>4,5</td><td>4,4</td></tr>
<tr><td>230</td><td>6,5</td><td>6,0</td></tr>
<tr><td>240</td><td>7,0</td><td>7,0</td></tr>
</table>

...

Table 2 : Partial safety factors specified in British and Singapore Standard as well as the customary yielding point of reinforcing steel and necessary bar diameters for evaluation of the maximum connection force of rebar in relation to the anchorage depth suitable for connection version ANCHORING

Country	Name of the Standard	Partial safety factor for		Yielding point of the steel f_{yk}	Bar diameter Ø
		Permanent Load	Steel		
[---]	[---]	[---]	[---]	[Mpa]	[mm]
Great Britain	BS 8110 : 1 - 1997	1,40	1,05	460	8, 10, 12, 14, 16, 20, 25, 28, 32, 36 and 40
Singapore	CP - 65 : 1999	1,40	1,15	460	8, 10, 13, 16, 20, 22, 25, 28, 32 and 40

...

Table 3 : Maximum connection force of rebar concerning "ANCHORING" as per British Standard BS 8110 : 1-1997 during exposure to fire for bar diameters of 8 to 14 mm in relation to anchorage depth, l, and a fire resistance time of 30 to 240 minutes

Nominal diameter of rebar	Drill hole diameter	Maximum force of rebar	Anchorage depth of rebar	Maximum force of rebar in conjunction with Hilti HIT-HY 150 (yielding point f_{yk} = 460 Mpa) in relation to fire resistance class					
Ø	D	$F_{s,T}$	l	F30	F60	F90	F120	F180	F240
mm	mm	kN	mm	kN	kN	kN	kN	kN	kN
8	10	15,73	65	1,96	0,74	0,19	0,04	0	0
			80	3,54	1,51	0,58	0,25	0	0
			95	6,18	2,49	1,26	0,69	0,11	0
			115	9,70	4,41	2,43	1,65	0,50	0,15
			150	15,73	10,13	6,13	4,05	2,09	1,06
			185		15,73	12,29	9,45	4,29	2,84
			205			15,73	12,97	5,69	4,15
			225				15,73	7,38	5,81
			275					15,73	14,02
			285						15,73
10	12	24,58	80	4,43	1,88	0,72	0,31	0	0
			100	8,83	3,55	1,88	1,10	0,22	0
			120	13,23	6,22	3,46	2,42	0,82	0,28
			140	17,62	10,46	5,62	4,12	1,92	0,88
			175	24,58	18,16	13,16	9,61	4,52	2,83
			205		24,58	19,76	16,21	7,12	5,18
			230			24,58	21,71	9,93	7,95
			245				24,58	13,07	10,93
			300					24,58	23,03
			310						24,58
12	16	35,39	95	9,27	3,73	1,88	1,04	0,17	0
			120	15,87	7,46	4,15	2,90	0,98	0,34
			145	22,47	13,87	7,97	5,50	2,71	1,32
			195	35,39	27,07	21,07	16,81	7,46	5,20
			230		35,39	30,31	26,05	11,91	9,54
			250			35,39	31,33	17,00	14,44
			270				35,39	22,28	19,72
			320					35,39	32,91
			330						35,39
14	18	48,17	110	15,44	6,73	3,65	2,38	0,62	0,13
			140	24,67	14,65	7,87	5,76	2,68	1,23
			170	33,91	23,88	16,89	11,92	5,76	3,47
			220	48,17	39,28	32,28	27,31	11,92	9,19
			250		48,17	41,52	36,55	19,84	16,85
			275			48,17	44,25	27,53	24,54
			290				48,17	32,15	29,16
			345					48,17	46,09
			355						48,17

Comments : Intermediate values may be obtained by linear interpolation. Extrapolating is not permitted.

...

Table 4 : Maximum connection force of rebar concerning "ANCHORING" as per British Standard BS 8110 : 1-1997 during exposure to fire for bar diameters of 16 to 25 mm in relation to anchorage depth, l, and a fire resistance time of 30 to 240 minutes

Nominal diameter of rebar	Drill hole diameter	Maximum force of rebar	Anchorage depth of rebar	Maximum force of rebar in conjunction with Hilti HIT-HY 150 (yielding point f_{yk} = 460 Mpa) in relation to fire resistance class					
Ø	D	$F_{s,T}$	l	F30	F60	F90	F120	F180	F240
mm	mm	kN	mm	kN	kN	kN	kN	kN	kN
16	20	62,92	130	24,68	13,22	6,99	5,18	2,11	0,85
			160	35,24	23,78	15,78	10,35	5,33	2,97
			190	45,79	34,33	26,34	20,66	9,25	6,28
			240	62,92	51,92	43,93	38,25	19,15	15,73
			275		62,92	56,25	50,57	31,47	28,05
			295			62,92	57,60	38,50	35,09
			315				62,92	45,54	42,12
			365					62,92	59,72
			375						62,92
20	25	98,31	160	44,05	29,72	19,73	12,94	6,66	3,71
			200	61,64	47,31	37,32	30,22	13,32	9,49
			285	98,31	84,70	74,71	67,61	43,73	39,46
			320		98,31	90,10	83,00	59,13	54,85
			340			98,31	91,80	67,92	63,65
			355				98,31	74,52	70,25
			410					98,31	94,44
			420						98,31
25	30	153,61	200	77,05	59,14	46,65	37,78	16,65	11,86
			250	104,54	86,63	74,14	65,27	35,42	30,08
			340	153,61	136,11	123,62	114,75	84,90	79,56
			375		153,61	142,86	133,99	104,14	98,80
			395			153,61	144,98	115,14	109,80
			415				153,61	126,14	120,79
			465					153,61	148,28
			475						153,61

Comments : Intermediate values may be obtained by linear interpolation. Extrapolating is not permitted.

...

Table 5 : Maximum connection force of rebar concerning "ANCHORING" as per Singapore Standard CP-65 : 1999 during exposure to fire for bar diameters of 8 to 16 mm in relation to anchorage depth, l, and a fire resistance time of 30 to 240 minutes

Nominal diameter of rebar	Drill hole diameter	Maximum force of rebar	Anchorage depth of rebar	Maximum force of rebar in conjunction with Hilti HIT-HY 150 (yielding point f_{yk} = 460 Mpa) in relation to fire resistance class					
Ø	D	$F_{s,T}$	l	F30	F60	F90	F120	F180	F240
mm	mm	kN	mm	kN	kN	kN	kN	kN	kN
8	10	14,36	65	1,96	0,74	0,19	0,04	0	0
			80	3,54	1,51	0,58	0,25	0	0
			95	6,18	2,49	1,26	0,69	0,11	0
			115	9,70	4,41	2,43	1,65	0,50	0,15
			145	14,36	9,25	5,32	3,67	1,81	0,88
			175		14,36	10,53	7,69	3,62	2,26
			200			14,36	12,09	5,33	3,80
			215				14,36	6,43	4,88
			270					14,36	13,14
			280						14,36
10	12	22,44	80	4,43	1,88	0,72	0,31	0	0
			100	8,83	3,55	1,88	1,10	0,22	0
			120	13,23	6,22	3,46	2,42	0,82	0,28
			140	17,62	10,46	5,62	4,12	1,92	0,88
			165	22,44	15,96	10,96	7,49	3,72	2,17
			195		22,44	17,56	14,01	6,22	4,34
			220			22,44	19,51	8,51	6,57
			235				22,44	10,95	8,89
			290					22,44	20,83
			300						22,44
13	18	37,92	105	12,91	5,43	2,92	1,82	0,43	0,06
			130	20,05	10,74	5,68	4,21	1,72	0,69
			155	27,20	17,89	11,39	7,49	3,86	2,06
			195	37,92	29,32	22,83	18,21	8,09	5,64
			230		37,92	32,84	28,22	12,91	10,33
			250			37,92	33,94	18,42	15,64
			265				37,92	22,71	19,93
			320					37,92	35,65
			330						37,92
16	20	57,45	130	24,68	13,22	6,99	5,18	2,11	0,85
			160	35,24	23,78	15,78	10,35	5,33	2,97
			225	57,45	46,65	38,65	32,97	14,75	11,61
			260		57,45	50,97	45,29	26,19	22,77
			280			57,45	52,33	33,23	29,81
			295				57,45	38,50	35,09
			350					57,45	54,44
			360						57,45

Comments : Intermediate values may be obtained by linear interpolation. Extrapolating is not permitted.

...

Table 6 : Maximum connection force of rebar concerning "ANCHORING" as per Singapore Standard CP-65 : 1999 during exposure to fire for bar diameters of 20 to 25 mm in relation to anchorage depth, l, and a fire resistance time of 30 to 240 minutes

Nominal diameter of rebar	Drill hole diameter	Maximum force of rebar	Anchorage depth of rebar	Maximum force of rebar in conjunction with Hilti HIT-HY 150 (yielding point f_{yk} = 460 Mpa) in relation to fire resistance class					
Ø	D	$F_{s,T}$	l	F30	F60	F90	F120	F180	F240
mm	mm	kN	mm	kN	kN	kN	kN	kN	kN
20	25	89,76	160	44,05	29,72	19,73	12,94	6,66	3,71
			200	61,64	47,31	37,32	30,22	13,32	9,49
			265	89,76	75,90	65,91	58,81	34,94	30,66
			300		89,76	81,30	74,20	50,33	46,06
			320			89,76	83,00	59,13	54,85
			340				89,76	67,92	63,65
			390					89,76	85,64
			400						89,76
22	28	108,61	175	55,71	39,95	28,96	21,15	9,95	6,22
			220	77,48	61,72	50,73	42,92	18,73	14,45
			285	108,61	93,17	82,18	74,37	48,11	43,40
			320		108,61	99,11	91,30	65,04	60,34
			340			108,61	100,98	74,71	70,01
			360				108,61	84,39	79,69
			415					108,61	106,30
			420						108,61
25	30	140,25	200	77,05	59,14	46,65	37,78	16,65	11,86
			250	104,54	86,63	74,14	65,27	35,42	30,08
			315	140,25	122,37	109,88	101,00	71,16	65,82
			350		140,25	129,12	120,24	90,40	85,06
			375			140,25	133,99	104,14	98,80
			390				140,25	112,39	107,05
			445					140,25	137,29
			455						140,25

Comments : Intermediate values may be obtained by linear interpolation. Extrapolating is not permitted.

Test Report

No. 3357/0550-5 -Nau- 1st issue
(July 30, 2002)

Applicant : Hilti Development Corporation
Hiltistrasse 6
D – 86 916 Kaufering

Order dated: February 13, 2001 Reference: Verbal Receipt: -

Order content :

Testing of

Hilti HIT-RE 500 injection systems in conjunction with reinforcing steel bars (rebar) of the BSt 500 S grade

set in small specimens (steel-encased concrete cylinders) of the grade ≥ C 20/25 which were subjected to pure tensile loading to ascertain their behaviour at high temperature in a fire according to DIN 4102-2 : 1977-09 respectively ISO 834 and to determine the pull-out behaviour as well as to develop a technical design concept for rebar connections suitable for fire protection

Receipt of test material :	07 CW 2000 to 06 CW 2001
Sampling :	The material testing laboratory has received no information about official sampling of the supplied material.
Marking :	None

This test report consists of 17 pages and 22 annexes.

The validity of this test report ceases on July 30, 2004.

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für das Bauwesen
Beethovenstraße 52
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Swift-Code: NOLADE 2H
USt.-ID-Nr. MPA-DE 183500654

Deutscher Akkreditierungs Rat DAR

Nach DIN EN ISO/IEC 17025 akkreditierte Prüflaboratorien: DAP-PL-2204.01 · DAP-PL-2204.02 · DAP-PL-2204.03 · DAP-PL-2204.04 · DAP-PL-2204.05
Nach DIN EN 45004 akkreditierte Inspektionsstelle: DAP-IS-2204.00 · Nach DIN EN 45001 akkreditiertes Kalibrierlaboratorium: DKD-K-22501-05
Die Akkreditierungen gelten für die in den Urkunden aufgeführten Prüfverfahren

1 Reason and Order

With request dated February 13, 2001, the Hilti Corporation assigned the MPA Braunschweig with the task of developing a technical design concept for rebar connections suitable for fire protection using reinforcing steel bars of BSt 500 S grade, 8 to 40 mm in diameter, and Hilti HIT-RE 500 injection adhesive in reinforced-concrete slabs and wall sections exposed to fire on one side (see section 5).

To lay the foundations for the determination of the thermomechanical properties, high-temperature investigations were carried out using small specimens (steel-encased concrete cylinders) which were subjected to pure tensile loading to ascertain the pull-out behaviour when exposed to fire in accordance with DIN 4102-2 : 1977-09 respectively ISO 834.

2 Description of tested arrangements

The tested Hilti HIT-RE 500 injection system gives an anchor fastening that exerts no expansion forces when set in normal concrete with quarzitic aggregates and subjected primarily to a static (dead) load.

The Hilti HIT-RE 500 injection system is an anchoring system with a working principle based on utilisation of the bond between steel, two-component adhesive and concrete. This injection system consists of a two-component injection adhesive ready for use in a dual foil pack that is based on an organic binder. It is injected by a dispenser through an interchangeable static forced mixer into a drilled hole. The Hilti HIT-RE 500 injection adhesive is a binder system, comprising an epoxy resin mixture and a hardener based on amine. Steel bar material of the grade BSt 500 S with a diameter of 8 to 20 mm was used as the reinforcing steel. Technical data sheets from the applicant provide a ruling on setting and loading the fastenings made with Hilti HIT-RE 500.

Structural details concerning the range of applications and design possibilities with the Hilti HIT-RE 500 injection system are shown in annex 1 of this test report.

A total of 36 rebar sections with a nominal diameter of 8 to 20 mm of the BSt 500 S grade were set in steel-encased concrete cylinders using Hilti HIT-RE 500 injection adhesive. They were tested subjected to pure tensile loading for their high-temperature behaviour when exposed to fire according to DIN 4102-2: 1977-02 and ISO 834 in order to determine the thermo-mechanical properties as well as the pull-out behaviour and to develop a technical design concept for the use of rebar connections suitable for fire protection.

The rebars were set with the Hilti HIT-RE 500 injection system in accordance with the applicant's technical data sheets, while using the pertaining setting tools specified in them, i.e. rotary hammer, drill bit, dispenser and static forced mixer.

Further details regarding the installation of the rebars in the concrete cylinders can be seen in annex 2 of this test report.

...

3 Test arrangement and realization

The tests were carried out in an electrically heated, servo-hydraulic, high-temperature test furnace. In the middle of a base surface of each concrete cylinder, a hole was drilled to a depth approximately 10 times the nominal rebar diameter and with a nominal diameter, d, of rebar diameter + 4 mm. After the holes had been cleaned, the rebars were set at an anchorage depth, l, of 10 times the rebar diameter using Hilti HIT-RE 500. Prior to setting each rebars, thermocouples were fastened to it in such a way that during the test the temperature in the injection adhesive at a depth about 10 mm below the concrete surface and on the lower end of the rebar at the bottom of the hole could be measured. The press cylinder of the test rig transferred the load centrally to the reinforcing bar.

Thermocouples fastened to the circumference of the concrete cylinders increased and measured the temperatures in the test rig. During the tests, the displacement of the rebars relative to the concrete surface was continuously plotted by a measuring device outside the rig.

Further design details of the test arrangement with the concrete cylinders in the test rig are given in annex 3 of this test report.

4 Test results

In the period from calendar week 07, 2000, to calendar week 06, 2001, 36 test specimens made with Hilti HIT-RE 500 injection system and rebar sections of steel grade BSt 500 S, 8 to 20 mm in nominal diameter, set in concrete cylinders of the grade ≥ C 20/25 were tested at high-temperature and subjected to pure tensile loading, to determine the pull-out behaviour as well as to develop a technical design concept suitable for fire protection according to DIN 4102-2: 1977-02 and ISO 834 for the use of rebar connections.

Based on the results when testing the high-temperature behaviour of the Hilti HIT-RE 500 injection mortar, the evaluation had to be expanded covering rebar connections with nominal diameters from 8 to 40 mm.

The results obtained when testing the Hilti HIT-RE 500 injection system, giving the failure temperatures, are compiled in following tables 1 and 2 (see pages 4 and 5).

...

Table 1 : Summary of test results obtained with Hilti HIT-RE 500 injection system using rebar sections of the steel grade BSt 500 S with a nominal diameter of 12 mm

Date of Testing	Nominal diameter of rebar [mm]	Anchorage depth l [mm]	Actual load N_{actual} [kN]	Failure Temperature [°C]
May 02, 2000	12	120	10.0	146
May 04, 2000			4.0	287
May 08, 2000			6.0	278
May 10, 2000			20.0	83
May 11, 2000			30.0	83
May 15, 2000			8.0	292
October 12, 2000			2.4	331
October 13, 2000			13.2	157
October 16, 2000			8.0	273
October 17, 2000			50.0	67
October 18, 2000			50.0	65
October 19, 2000			24.8	70
November 10, 2000			9.2	287
November 13, 2000			10.0	148
November 14, 2000			9.6	157
November 15, 2000			15.2	89
November 22, 2000			12.0	145
November 23, 2000			55.2	61
November 24, 2000			40.0	59
November 27, 2000			60.0	57
November 13, 2000		60 [2)]	49.6 [1)]	20
November 13, 2000			52.4 [1)]	20
January 15, 2001			36.0	49
January 24, 2001			44.0	43
February 01, 2001			18.0	57

1) These tests were carried out by the Hilti Development Corporation at Kaufering, Germany. The values are the means of 5 results in each case.

2) During these tests, an anchorage depth of only l = 5 x diameter was used to ensure that a bond failure would be obtained each time.

...

Table 2 : Summary of test results obtained with Hilti HIT-RE 500 injection system using rebar sections of the steel grade BSt 500 S with a nominal diameter of 8, 10, 14, 16 and 20 mm

Date of Testing	Nominal diameter of rebar [mm]	Anchorage depth l [mm]	Actual load N_{actual} [kN]	Failure Temperature [°C]
May 24, 2000	**8**	80	3.2	281
May 25, 2000			9.2	72
May 29, 2000	**10**	100	15.2	71
June 05, 2000			5.2	291
November 16, 2000	**14**	140	20.0	108
January 16, 2001			44.0	106
January 18, 2001			12.0	148
November 17, 2000	**16**	160	20.0	124
December 07, 2000			80.0	57
January 02, 2001	**20**	200	25.2	134
February 02, 2001		100 1)	38.0	63

1) During this test, an anchorage depth of only l = 5 x diameter was used to ensure that a bond failure would be obtained.

5 Technical design concept suitable for fire protection for rebar connections using Hilti HIT-RE 500 injection system

5.1 General aspects

Based on the results when testing the high-temperature behaviour of Hilti HIT-RE 500 injection system, as given in section 4, a technical design concept for use of rebar connections, 8 to 40 mm in diameter, suitable for fire protection according to DIN 4102-2 : 1977-09 respectively ISO 834, made in reinforced-concrete slabs and wall sections when exposed to fire on one side, had to be developed for a fire resistance time of 30 to 240 minutes in accordance with the client's request.

This technical design concept should include both rebar connection versions, namely "OVERLAP JOINT" and "ANCHORING". These two connection variants are shown schematically in the following figures 1 and 2 (see page 7).

Fig. 1 : Schematic depiction of rebar connection version OVERLAPED JOINT

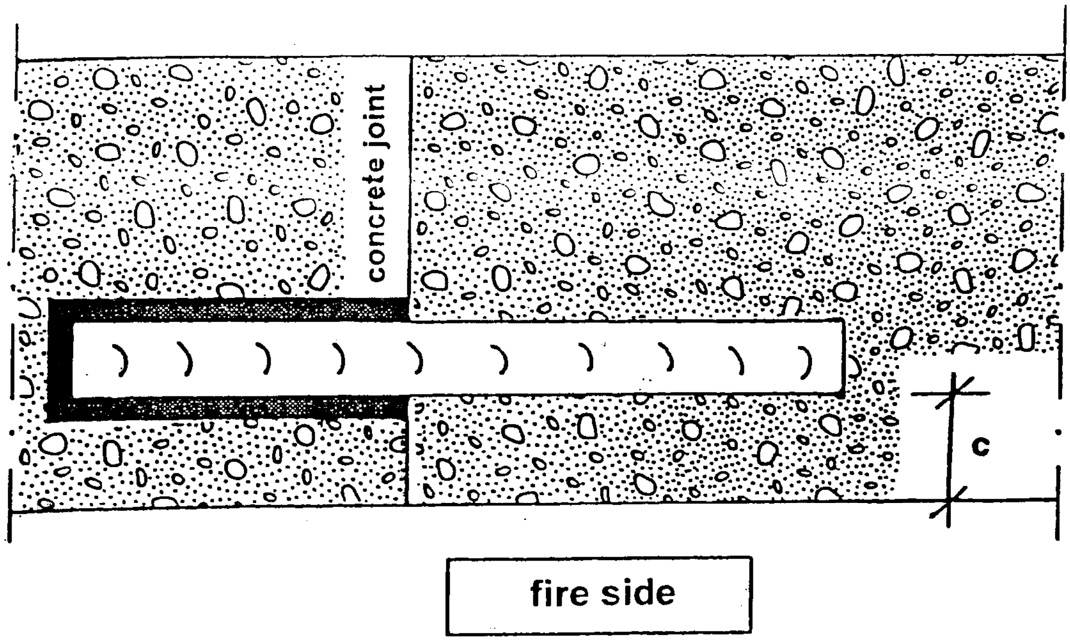
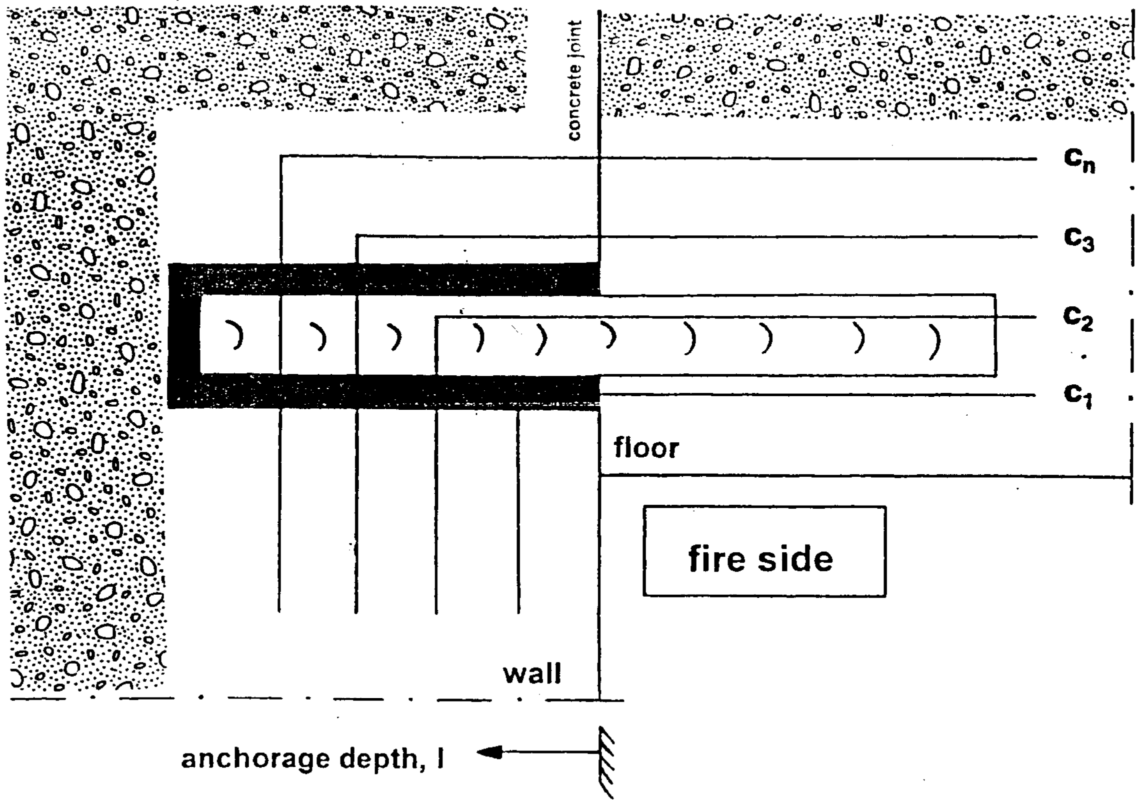


Fig. 2 : Schematic depiction of rebar connection version ANCHORING



5.2 Fundamentals and reference literature

Fundamentals for the technical design concept suitable for fire protection are as follows :

[1] DIN 1045, 1988-12, (Concrete and reinforced concrete, design and construction)

[2] DIN V ENV 1992 part 1-1 (issue 1992-06), Eurocode 2 (Planning of reinforced-concrete and prestressed-concrete structures; part 1 : Fundamentals and application regulations for building construction)

[3] DIN 1045 : 2001-07, (Structures of concrete, reinforced concrete and prestressed concrete)

[4] DIN 4102 - 2 : 1977-09 (ISO 834), (Behaviour in fire of building materials and components. Building components, terms, requirements and tests)

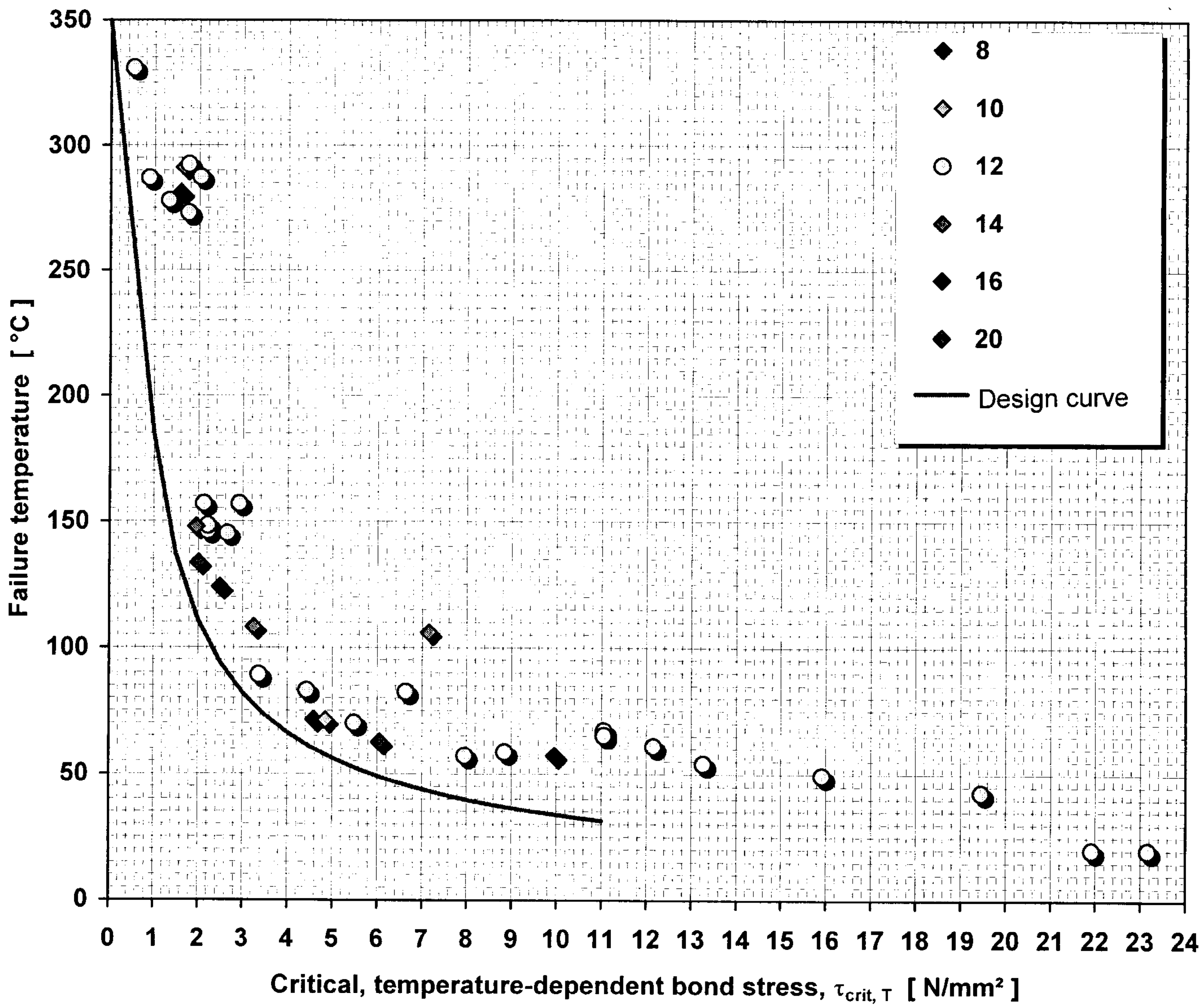
[5] (Concrete-fire protection manual). Prof. Dr.-Ing. Dr.-Ing. h.c. K. Kordina and Dr.-Ing. C. Meyer-Ottens, issue 1981

...

5.3 Evaluation of test results and design

As the design of rebar connections is generally based on the utilisation of bond stresses, the test results obtained with Hilti HIT-RE 500 injection adhesive, as given in tables 1 and 2 (see pages 4 and 5), have been depicted in the following fig. 3 as a function of the failure temperature and the pertaining critical bond stress, $\tau_{crit,T}$. In addition, a design curve, kept on the safe side and below the actual failure values, was configured in fig. 3, taking into account the test results and based on the experiences gained while testing.

Fig. 3 : Graphical presentation of test results obtained with Hilti HIT-RE 500 injection adhesive as well as the design curve as a function of failure temperature and critical, temperature-dependent bond stress, $\tau_{crit,T}$



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Using the knowledge about the heat-up behaviour of concrete as per [5] (see fig. 4), the design curve from fig. 3 (see page 8) as well as further experiences from testing normal concrete with quarzitic aggregates, critical temperature-dependent bond stresses, $\tau_{crit,T}$, can be provided on the safe side in table 3 (see page 10) in relation to the respective concrete coverage, c, for a fire resistance time of 30 to 240 minutes.

Fig. 4 : Temperature distribution as per DIN 4102 - 2 : 1977-09 and ISO 834 in slabs and wall sections of normal concrete with quarzitic aggregates when exposed to fire on one side; from [5], page 141

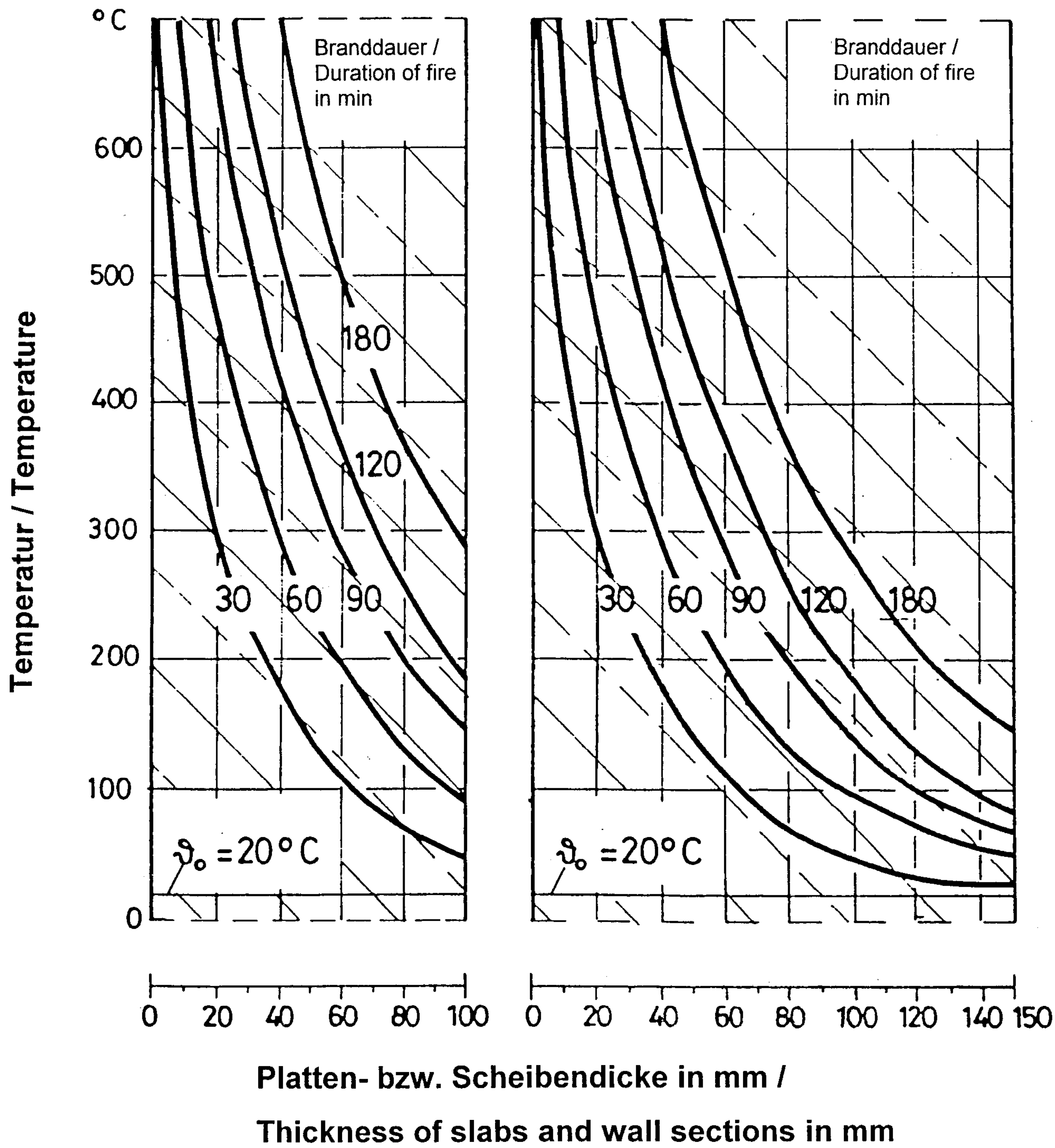

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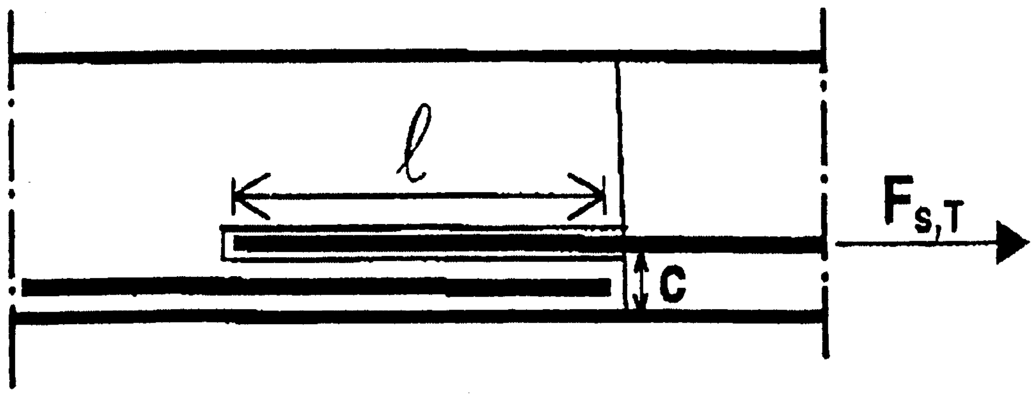
Table 3 : Critical, temperature-dependent bond stresses, $\tau_{crit,T}$, for Hilti HIT-RE 500 injection adhesive in relation to fire resistance times of 30 to 240 minutes and the required minimum concrete coverage, c

concrete coverage	Critical, temperature-dependent bond stresses, $\tau_{crit,T}$, for Hilti HIT-RE 500 injection adhesive in relation to fire resistance class					
c [mm]	F30 [N/mm²]	F60 [N/mm²]	F90 [N/mm²]	F120 [N/mm²]	F180 [N/mm²]	F240 [N/mm²]
10	0					
20	0.494	0				
30	0.665		0	0		
40	0.897	0.481			0	
50	1.209	0.623				0
60	1.630	0.806	0.513			
70	2.197	1.043	0.655	0.487		
80	2.962	1.351	0.835	0.614		
90	3.992	1.748	1.065	0.775	0.457	
100	5.382	2.263	1.358	0.977	0.553	
110	7.255	2.930	1.733	1.233	0.669	0.469
120	9.780	3.792	2.210	1.556	0.810	0.551
130		4.909	2.818	1.963	0.980	0.647
140		6.355	3.594	2.477	1.185	0.759
150		8.226	4.584	3.125	1.434	0.892
160		10.649	5.846	3.943	1.735	1.047
170			7.456	4.974	2.099	1.230
180			9.510	6.276	2.540	1.445
190				7.918	3.073	1.697
200				9.990	3.718	1.993
210					4.498	2.341
220	11.000				5.442	2.749
230					6.584	3.228
240		11.000			7.966	3.792
250			11.000		9.639	4.453
260				11.000		5.230
270						6.143
280					11.000	7.214
290						8.473
300						9.951
310						11.000

5.4 Application of design concept to rebar connection version OVERLAP JOINT

Verification of the suitability of overlap joints exposed to temperature must be calculated using the following formula. Fig. 5 below shows, schematically, the rebar connection version OVERLAP JOINT.

Fig. 5 : Schematic depiction of the connection version OVERLAP JOINT



$$F_{s,T} \leq l \cdot d_s \cdot \pi \cdot \tau_{crit,T}$$

Whereby :

$F_{s,T}$ Force in the reinforcing bar when subjected to fire exposure

l Length of overlap joint

d_s Nominal diameter of the reinforcing bar

$\tau_{crit,T}$ Critical, temperature-dependent bond stress as per table 3 based on consideration of the concrete coverage, c

Evaluations of the critical, temperature-dependent bond stress, $\tau_{crit,T}$, in relation to the concrete coverage, c, and the respective, stipulated fire resistance time of rebar connection version OVERLAP JOINT are shown in table 3 (see page 10). In this respect, the overlap joint length may not exceed 80 times the nominal rebar diameter, d_s, when the joint is exposed to fire.

...

It can be seen from figs 1 (see page 6) and 5 (see page 11) that in the case of this rebar connection version the entire anchoring range of the reinforcement is parallel to the surface of the building component when exposed to fire and, thus, in principle, is within a single temperature zone which is decisive for the load bearing capacity. Consequently, increasing the anchorage depth respectively the overlap joint length for this version of a rebar connection is not meaningful.

As the concrete coverage, c, is the only protection against increase in temperatures, it would be possible to achieve full utilisation with respect to the maximum permissible force in the rebar by extending the concrete coverage.

An alternative to increasing the concrete coverage can be seen, to a certain extent, in a larger amount of joint reinforcement in the connection, depending on the degree of utilisation.

On the other hand, the passive fire protection requirements can also be met by plaster coatings or other claddings, if their suitability is verified, e.g. mineral fibre slabs of building material class A with a melting point ≥ 1000 °C and a bulk density ≥ 150 kg/m^3 as well as calcium silicate or vermiculite panels.

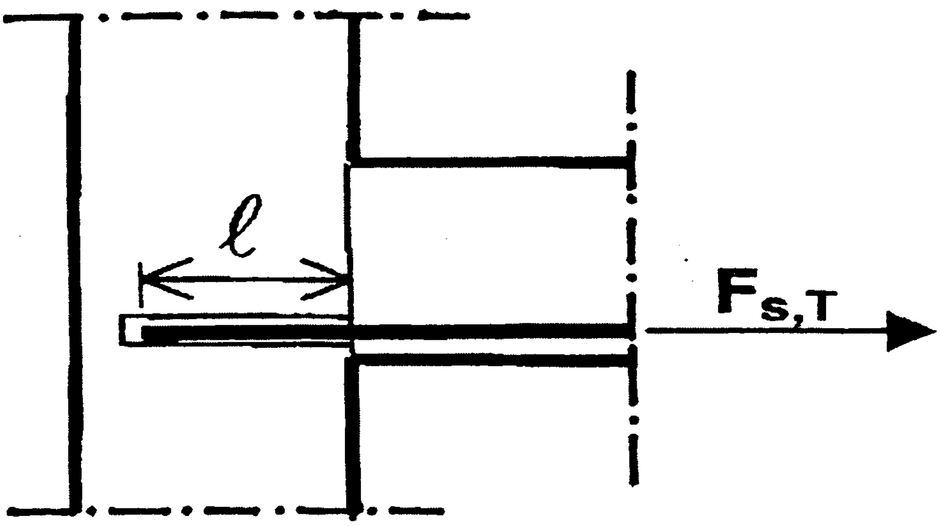
An equivalent thickness of concrete layer may be used for this kind of cladding (1 cm of cladding thickness = 2 cm of concrete coverage). The fastening of the cladding must also meet the passive fire protection requirements and be verified separately.

...

5.5 Application of design concept to rebar connection version ANCHORING

Verification of the suitability of anchored rebars exposed to temperature must be calculated using the following formula. Fig. 6 below shows, schematically, the rebar connection version ANCHORING.

Fig. 6 : Schematic depiction of the connection version ANCHORING



$$F_{s,T} \leq A_s \cdot \sigma_s$$

Whereby :

$F_{s,T}$ Force in the reinforcing bar when subjected to fire exposure

A_s Cross-sectional area of the reinforcing bar

σ_s Stress in steel transferable to the concrete joint through the injection adhesive in relation to the anchorage depth, l, of the reinforcing bar and the fire resistance time

Verification of the design of connection version ANCHORING is provided on basis of integration of the critical, temperature-dependent bond stress, $\tau_{crit,T}$, in relation to the rebar anchorage depth, l, and the fire resistance time.

...

It can be seen in figs 2 (see page 7) and 6 (see page 13) that in case of this version of a rebar connection the anchoring range of the reinforcement is vertical to the surface of the building component when exposed to fire and thus comes within differing temperature zones. In view of this, full utilisation of the maximum permissible force in the rebar is possible for the connection version ANCHORING by increasing the anchorage depth, l. An alternative to this can be seen to be in a larger amount of connection reinforcement as a function of the fire resistance time. Furthermore, an equivalent thickness of concrete layer can be made in the form of cladding, as described in section 5.4.

This type of rebar connections should be evaluated for various countries, while taking into consideration the partial safety factors from the respective country-specific, reinforced-concrete construction standard (see annex 4) as a function of the force in the rebar and the rebar anchorage depth (see annexes 5 to 22).

6 Conclusions

In the period from calendar week 07, 2000, to calendar week 06, 2001, 36 test specimens made with Hilti HIT-RE 500 injection system and rebar sections of steel grade BSt 500 S, 8 to 20 mm in nominal diameter, set in concrete cylinders of the grade ≥ C 20/25 were tested on their high temperature behaviour in fire conditions according to DIN 4102-2: 1977-02 and ISO 834 and subjected to pure tensile loading to determine the pull-out behaviour.

By means of the test results obtained with Hilti HIT-RE 500 injection adhesive system, it is possible to calculate on the safe side critical, temperature-dependent bond stresses, $\tau_{crit,T}$, in relation to the respective concrete coverage, c, for a fire resistance time of 30 to 240 minutes. These, among other aspects, provided the basis for the requested technical design concept for the application of rebar connections suitable for fire protection.

Based on the temperature-dependent bond stress, $\tau_{crit,T}$, rulings have been provided in the technical design concept for the required concrete coverage, c, and rebar connection version OVERLAP JOINT, as per section 5.4, as well as for the required anchorage depth, l, and connection version ANCHORING, as per section 5.5, for Hilti HIT-RE 500 injection system using nominal diameters of rebars from 8 to 40 mm in relation to the respective fire resistance class.

Verification of the loading capacity of adhesive bonded overlap joints or anchored rebars exposed to fire according to DIN 4102-2 : 1977-09 respectively ISO 834 must be provided at the same time as verification of the serviceability state in accordance with the country-specific reinforced-concrete standards. Here, the larger calculated value concerning the overlap joint length or the rebar anchorage depth is decisive.

...

7 Special notes

7.1 This evaluation applies only to rebar connections, 8 to 40 mm in nominal diameter, in conjunction with the Hilti HIT-RE 500 injection adhesive (current standard formulation), when taking into account the general conditions given in the client's technical data sheets for the rebar connection versions **OVERLAP JOINT** and **ANCHORING**.

7.2 The evaluation for rebar connections made with Hilti HIT-RE 500 injection adhesive applies only in conjunction with reinforced-concrete slabs or walls which are exposed to fire on one side and can be classified in at least a fire resistance class corresponding to the fire resistance time of the injection adhesive.

7.3 The validity of this test report ceases on July 30, 2004.

Director
on behalf

RD Dr.-Ing. Wesche

Test engineer

RR Dipl.-Ing. Nause

Braunschweig, July 30, 2002

See page 16 and 17 for a list of annexes

List of annexes

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List of annexes

Annexes 19 and 20 : Evaluation of the maximum forces in rebars for the connection version ANCHORING according to **Australian Standard AS 3600 - 2001**, using reinforcing bars with a yielding point of $\mathbf{f_{yk}}$ **= 400 Mpa**, as a function of the fire resistance time

Annexes 21 and 22 : Evaluation of the maximum forces in rebars for the connection version ANCHORING according to **Australian Standard AS 3600 - 2001**, using reinforcing bars with a yielding point of $\mathbf{f_{yk}}$ **= 500 Mpa**, as a function of the fire resistance time

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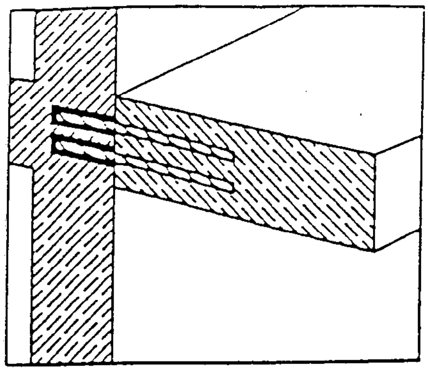
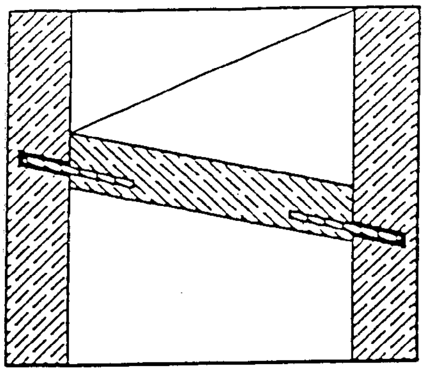
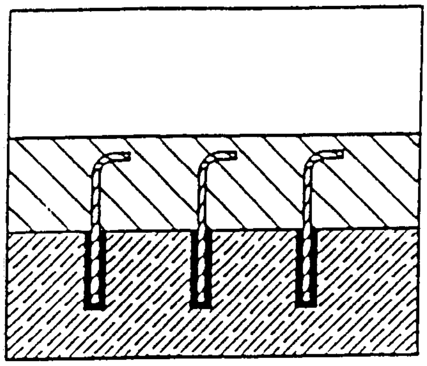


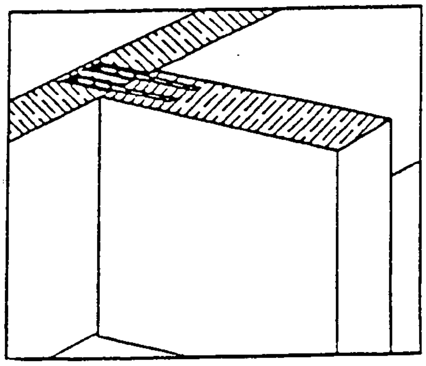
Balcony connection



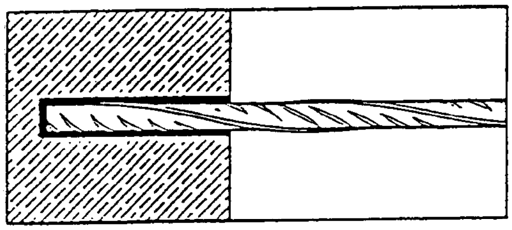
Floor connection



Concrete overlay connection



Wall connection

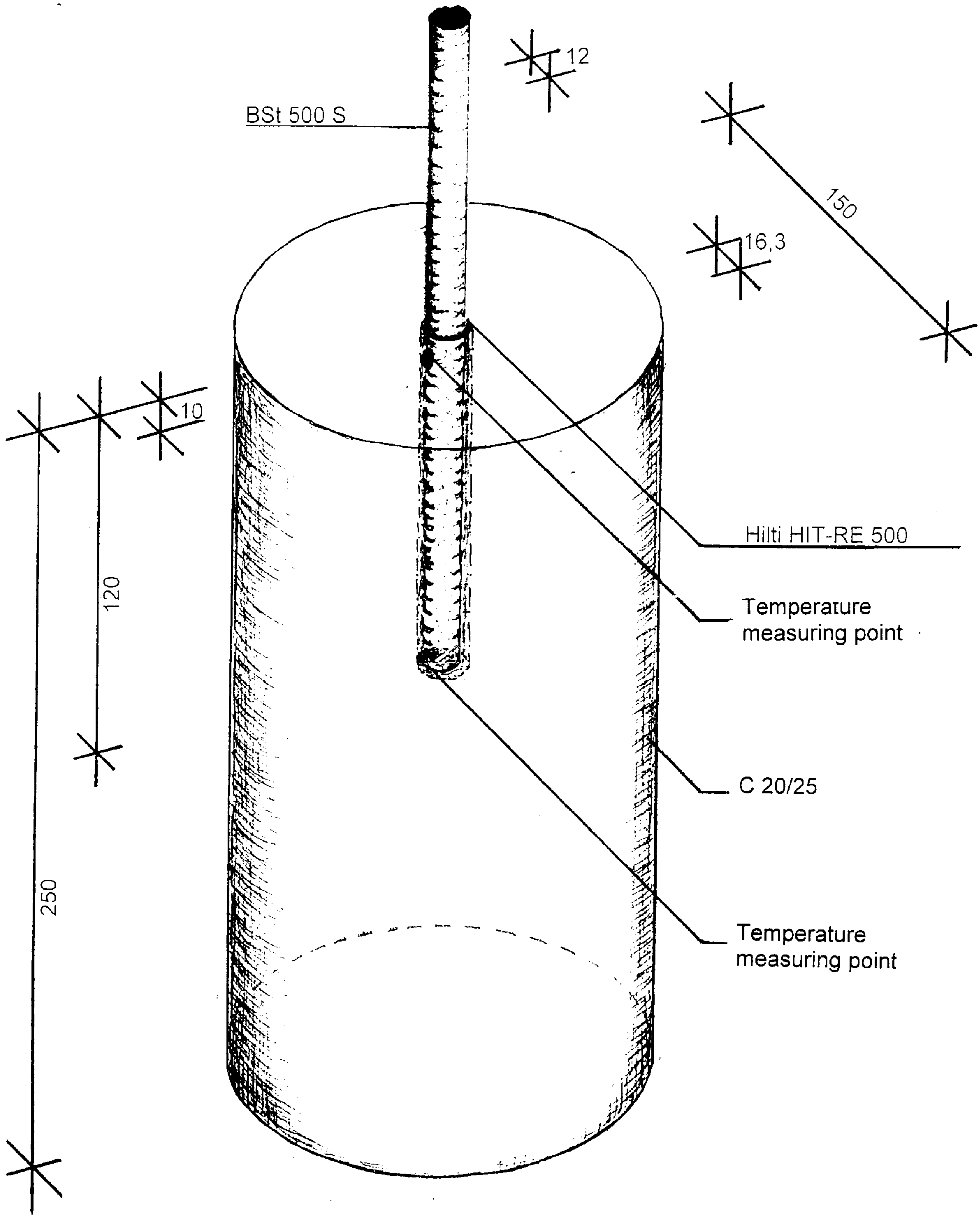


- Fastening of rebars
- As cast in
- High loads
- Design based on steel yield strength
- Design as per Eurocode 2
- Concrete and hard natural stone
- High level of safety / reliability
- Minimal displacement
- Small diameter of drilled hole
- Containing no styrene

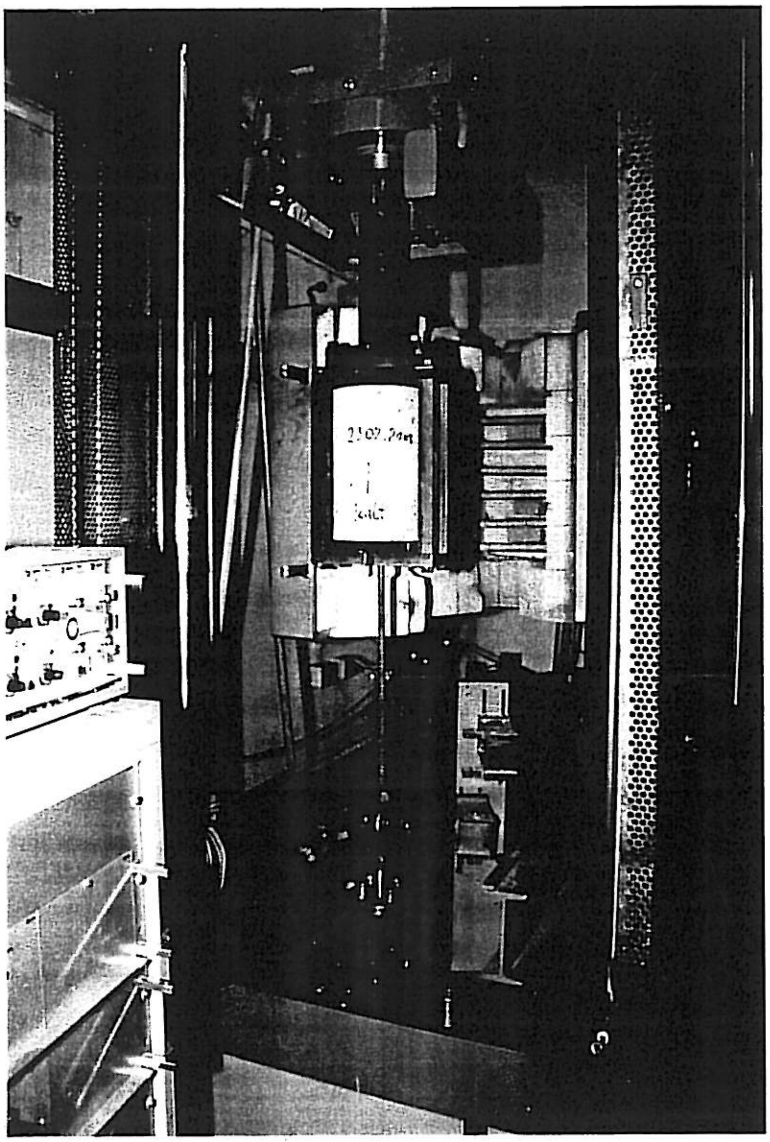
- Automatic opening
- Reliable mixing
- Accurate dispensing
- Application friendly
- A coordinated complete system

Fields of application and design possibilities of Hilti HIT-RE 500 injection system	Annex 1 of Test Report No. 3357/0550-5 -Nau- dated July 30, 2002
Materialprüfanstalt für das Bauwesen Institut für Baustoffe, Massivbau und Brandschutz Technische Universität Braunschweig	

Test arrangement of rebars



Test arrangement of rebars	Annex 2 of Test Report No. 3357/0550-5 -Nau- dated July 30, 2002
Materialprüfanstalt für das Bauwesen Institut für Baustoffe, Massivbau und Brandschutz Technische Universität Braunschweig	



Prüfeinrichtung mit eingebautem Prüfkörper

Anlage 3 zum Untersuchungs-bericht Nr. 3357/0550-5

Materialprüfanstalt für das Bauwesen
Institut für Baustoffe, Massivbau und Brandschutz
Technische Universität Braunschweig

Parameters specific to country for evaluating the maximum permissible force in a rebar as a function of the anchorage depth for the rebar connection version ANCHORING

Name of the Standard [---]	Country [---]	Partial safety factor for Permanent Load [---]	Partial safety factor for Steel [---]	Yielding point of the steel f_{yk} [N/mm²]	Rebar Diameter dia. [mm]
DIN 1045 - 1988	Germany	1.75		500	8, 10, 12, 14, 16, 20, 25, 32, 36 and 40
DIN 1045 - 2001	Germany	1.35	1.15	500	8, 10, 12, 14, 16, 20, 25, 32, 36 and 40
EC 2 - 1992	Europe	1.35	1.15	500	8, 10, 12, 14, 16, 20, 25, 32, 36 and 40
B 4700 - 2000	Austria	1.35	1.15	550	8, 10, 12, 14, 16, 20, 26, 30, 36 and 40
BS 8110 : 1 - 1997	Great Britain	1.40	1.05	460	8, 10, 12, 14, 16, 20, 25, 28, 32, 36 and 40
CP - 65 : 1999	Singapore	1.40	1.15	460	8, 10, 13, 16, 20, 22, 25, 28, 32 and 40
AS 3600 - 2001	Australia	1.25	0.80 *)	400 500	8, 10, 12, 16, 20, 22, 25, 28, 32 and 40

*) Reduction factor which must be added to the numerator.

Maximum connection force of rebar as per German Standard DIN 1045 – 1988 concerning ANCHORING during exposure to fire in relation to fire resistance times from 30 to 240 Minutes

Nominal rebar diameter	Drill hole diameter	Maximum force in rebar	Anchorage depth	Maximum force in rebar in conjunction with Hilti HIT-RE 500 (yielding point f_{yk} = 500 N/mm²) as a function of fire resistance class					
dia.	D	$F_{s,T}$	L	F30	F60	F90	F120	F180	F240
mm	mm	kN	mm	kN	kN	kN	kN	kN	kN
8	10	14.36	65	1.38	0.57	0.19	0.05	0	0
			80	2.35	1.02	0.47	0.26	0	0
			95	3.87	1.68	0.88	0.55	0.12	0
			115	7.30	3.07	1.71	1.14	0.44	0.18
			145	14.36	7.12	4.01	2.74	1.23	0.69
			175		14.36	8.80	5.96	2.62	1.52
			200			14.36	11.00	4.57	2.59
			215				14.36	6.27	3.48
			260					14.36	7.86
			300						14.36
10	12	22.44	80	2.94	1.27	0.59	0.33	0	0
			100	5.68	2.45	1.31	0.85	0.24	0
			120	10.66	4.44	2.48	1.68	0.68	0.31
			140	17.57	7.76	4.38	2.99	1.33	0.73
			155	22.44	11.66	6.55	4.47	2.01	1.15
			190		22.44	15.91	10.78	4.59	2.64
			210			22.44	17.21	7.06	3.95
			230				22.44	10.66	5.75
			270					22.44	11.68
			310						22.44
12	16	32.31	95	5.80	2.52	1.32	0.83	0.18	0
			120	12.79	5.33	2.97	2.01	0.82	0.37
			145	23.16	10.68	6.02	4.12	1.84	1.03
			170	32.31	20.15	11.61	7.88	3.49	2.03
			200		32.31	23.24	16.50	6.85	3.89
			225			32.31	26.87	11.55	6.29
			240				32.31	15.66	8.28
			285					32.31	18.10
			325						32.31
14	18	43.98	110	10.92	4.65	2.55	1.70	0.61	0.20
			140	24.60	10.87	6.13	4.19	1.86	1.03
			170	39.12	23.50	13.55	9.20	4.07	2.37
			185	43.98	30.76	19.85	13.36	5.75	3.32
			215		43.98	34.36	26.51	10.97	6.08
			235			43.98	36.18	16.52	8.82
			255				43.98	24.65	12.60
			295					43.98	25.00
			335						43.98
16	20	57.45	130	22.59	9.42	5.30	3.61	1.56	0.80
			160	39.17	21.33	11.95	8.15	3.65	2.11
			195	57.45	40.69	28.22	19.49	8.20	4.68
			230		57.45	47.57	38.59	17.06	9.20
			250			57.45	49.65	25.51	13.19
			265				57.45	33.70	17.14
			310					57.45	36.55
			350						57.45

Comments : Intermediate values may be obtained by linear interpolation. Extrapolating is not permitted.

Evaluation of the maximum forces in rebars according to DIN 1045 - 1988 for a nominal bar diameter from 8 to 16 mm

Materialprüfanstalt für das Bauwesen
Institut für Baustoffe, Massivbau und Brandschutz
Technische Universität Braunschweig

Annex 5 of Test Report No. 3357/0550-5 -Nau- dated July 30, 2002

Maximum connection force of rebar as per German Standard DIN 1045 – 1988 concerning ANCHORING during exposure to fire in relation to fire resistance times from 30 to 240 Minutes

Nominal rebar diameter	Drill hole diameter	Maximum force in rebar	Anchorage depth	Maximum force in rebar in conjunction with Hilti HIT-RE 500 (yielding point f_{yk} = 500 N/mm²) as a function of fire resistance class					
dia.	D	$F_{s,T}$	L	F30	F60	F90	F120	F180	F240
mm	mm	kN	mm	kN	kN	kN	kN	kN	kN
20	25	89.76	160	48.97	26.67	14.93	10.18	4.56	2.64
			200	76.61	54.31	38.73	27.50	11.42	6.48
			220	89.76	68.14	52.55	41.32	17.38	9.56
			255		89.76	76.74	65.51	35.22	18.00
			275			89.76	79.34	49.04	25.45
			295				89.76	62.86	35.72
			335					89.76	62.96
			375						89.76
25	30	140.25	200	95.77	67.89	48.41	34.37	14.27	8.10
			250	138.96	111.09	91.60	77.57	39.86	20.61
			255	140.25	115.41	95.92	81.89	44.02	22.50
			285		140.25	121.84	107.81	69.94	37.71
			310			140.25	129.41	91.54	57.11
			325				140.25	104.50	70.07
			370					140.25	108.94
			410						140.25
32	40	229.79	255	183.40	147.72	122.78	104.82	56.35	28.80
			275	205.52	169.84	144.90	126.94	78.46	40.71
			300	229.79	197.48	172.54	154.58	106.11	62.15
			330		229.79	205.72	187.76	139.28	95.21
			355			229.79	215.40	166.93	122.86
			370				229.79	183.52	139.45
			415					229.79	189.21
			455						229.79
36	44	290.82	290	249.87	209.73	181.67	161.46	106.93	59.10
			305	268.53	228.39	200.33	180.13	125.59	76.01
			325	290.82	253.27	225.21	205.01	150.47	100.89
			360		290.82	268.76	248.55	194.02	144.44
			380			290.82	273.43	218.90	169.32
			395				290.82	237.56	187.98
			440					290.82	243.96
			480						290.82
40	47	359.04	320	319.10	274.50	243.33	220.87	160.28	105.19
			335	339.84	295.24	264.06	241.61	181.02	125.93
			350	359.04	315.97	284.80	262.34	201.75	146.66
			385		359.04	333.18	310.72	250.13	195.04
			405			359.04	338.37	277.78	222.69
			420				359.04	298.51	243.42
			465					359.04	305.63
			505						359.04

Comments : Intermediate values may be obtained by linear interpolation. Extrapolating is not permitted.

Evaluation of the maximum forces in rebars according to DIN 1045 - 1988 for a nominal bar diameter from 20 to 40 mm

Materialprüfanstalt für das Bauwesen
Institut für Baustoffe, Massivbau und Brandschutz
Technische Universität Braunschweig

Annex 6 of Test Report No. 3357/0550-5 -Nau- dated July 30, 2002

Maximale Stabkräfte gemäß DIN 1045 – 2001 bzw. EC 2 - 1992 unter Brandbeanspruchung für die Bewehrungsanschlußvariante VERANKERUNG bezogen auf Feuerwiderstandsdauern von 30 bis 240 Minuten

Nenndurchmesser	Bohrlochdurchmesser	Maximale Stabkraft	Verankerungstiefe	Maximale Stabkraft in Verbindung mit Hilti HIT-RE 500 (Streckgrenze f_{yk} = 500 N/mm²) in Abhängigkeit von der Feuerwiderstandsdauer					
Ø	D	$F_{s,T}$	L	F30	F60	F90	F120	F180	F240
mm	mm	kN	mm	kN	kN	kN	kN	kN	kN
8	10	16.19	65	1.38	0.57	0.19	0.05	0	0
			80	2.35	1.02	0.47	0.26	0	0
			95	3.87	1.68	0.88	0.55	0.12	0
			115	7.30	3.07	1.71	1.14	0.44	0.18
			150	16.19	8.15	4.59	3.14	1.41	0.80
			180		16.19	9.99	6.75	2.94	1.70
			205			16.19	12.38	5.08	2.86
			220				16.19	6.95	3.82
			265					16.19	8.57
			305						16.19
10	12	25.29	80	2.94	1.27	0.59	0.33	0	0
			100	5.68	2.45	1.31	0.85	0.24	0
			120	10.66	4.44	2.48	1.68	0.68	0.31
			140	17.57	7.76	4.38	2.99	1.33	0.73
			165	25.29	15.06	8.50	5.79	2.58	1.50
			195		25.29	17.63	12.18	5.12	2.93
			220			25.29	20.66	8.69	4.78
			235				25.29	11.80	6.30
			280					25.29	13.86
			320						25.29
12	16	36.42	95	5.80	2.52	1.32	0.83	0.18	0
			120	12.79	5.33	2.97	2.01	0.82	0.37
			145	23.16	10.68	6.02	4.12	1.84	1.03
			180	36.42	24.29	14.99	10.12	4.41	2.55
			210		36.42	27.38	20.65	8.47	4.74
			235			36.42	31.01	14.16	7.56
			250				36.42	19.13	9.89
			295					36.42	21.43
			335						36.42
14	18	49.58	110	10.92	4.65	2.55	1.70	0.61	0.20
			140	24.60	10.87	6.13	4.19	1.86	1.03
			170	39.12	23.50	13.55	9.20	4.07	2.37
			195	49.58	35.60	24.69	17.05	7.17	4.10
			225		49.58	39.20	31.34	13.48	7.34
			250			49.58	43.44	22.32	11.54
			265				49.58	29.49	15.00
			310					49.58	31.98
			350						49.58
16	20	64.75	130	22.59	9.42	5.30	3.61	1.56	0.80
			160	39.17	21.33	11.95	8.15	3.65	2.11
			190	55.76	37.92	25.45	17.25	7.35	4.22
			210	64.75	48.98	36.51	27.53	11.29	6.32
			240		64.75	53.10	44.12	20.88	11.04
			265			64.75	57.94	33.70	17.14
			280				64.75	42.00	22.17
			325					64.75	44.84
			365						64.75

Hinweis : Zwischenwerte dürfen linear interpoliert werden. Eine Extrapolation ist nicht erlaubt.

Evaluation of the maximum forces in rebars according to DIN 1045 - 2001 and Eurocode 2 – 1992 for a nominal bar diameter from 8 to 16 mm (in German)

Materialprüfanstalt für das Bauwesen
Institut für Baustoffe, Massivbau und Brandschutz
Technische Universität Braunschweig

Maximale Stabkräfte gemäß DIN 1045 – 2001 bzw. EC 2 - 1992 unter Brandbeanspruchung für die Bewehrungsanschlußvariante VERANKERUNG bezogen auf Feuerwiderstandsdauern von 30 bis 240 Minuten

Nenn-durch-messer	Bohrloch-durch-messer	Maximale Stab-kraft	Ver-ankerungs-tiefe	Maximale Stabkraft in Verbindung mit Hilti HIT-RE 500 (Streckgrenze f_{yk} = 500 N/mm²) in Abhängigkeit von der Feuerwiderstandsdauer					
Ø	D	$F_{s,T}$	L	F30	F60	F90	F120	F180	F240
mm	mm	kN	mm	kN	kN	kN	kN	kN	kN
20	25	101.18	160	48.97	26.67	14.93	10.18	4.56	2.64
			200	76.61	54.31	38.73	27.50	11.42	6.48
			240	101.18	81.96	66.37	55.15	26.10	13.80
			270		101.18	87.11	75.88	45.58	23.36
			295			101.18	93.16	62.86	35.72
			310				101.18	73.23	45.69
			355					101.18	76.79
			395						101.18
25	30	158.09	200	95.77	67.89	48.41	34.37	14.27	8.10
			250	138.96	111.09	91.60	77.57	39.86	20.61
			275	158.09	132.69	113.20	99.17	61.30	31.81
			305		158.09	139.12	125.09	87.22	52.79
			330			158.09	146.69	108.82	74.39
			345				158.09	121.77	87.34
			390					158.09	126.22
			430						158.09
32	40	259.02	255	183.40	147.72	122.78	104.82	56.35	28.80
			275	205.52	169.84	144.90	126.94	78.46	40.71
			325	259.02	225.13	200.19	182.23	133.75	89.68
			360		259.02	238.89	220.93	172.46	128.39
			380			259.02	243.05	194.58	150.51
			395				259.02	211.16	167.09
			440					259.02	216.86
			480						259.02
36	44	327.82	290	249.87	209.73	181.67	161.46	106.93	59.10
			325	293.41	253.27	225.21	205.01	150.47	100.89
			355	327.82	290.59	262.54	242.33	187.80	138.22
			385		327.82	299.86	279.65	225.12	175.54
			410			327.82	310.75	256.22	206.64
			425				327.82	274.88	225.30
			470					327.82	281.28
			510						327.82
40	47	404.71	320	319.10	274.50	243.33	220.87	160.28	105.19
			355	367.48	322.88	291.71	269.25	208.66	153.57
			385	404.71	364.35	333.18	310.72	250.13	195.04
			415		404.71	374.64	352.19	291.60	236.51
			440			404.71	386.75	326.16	271.07
			455				404.71	346.89	291.80
			500					404.71	354.01
			540						404.71

Hinweis : Zwischenwerte dürfen linear interpoliert werden. Eine Extrapolation ist nicht erlaubt.

Evaluation of the maximum forces in rebars according to DIN 1045 - 2001 and Eurocode 2 – 1992 for a nominal bar diameter from 20 to 40 mm (in German)

Annex 8 of Test Report No. 3357/0550-5 -Nau- dated July 30, 2002

Materialprüfanstalt für das Bauwesen
Institut für Baustoffe, Massivbau und Brandschutz
Technische Universität Braunschweig

Maximum connection force of rebar as per Eurocode 2 - 1992 concerning ANCHORING during exposure to fire in relation to fire resistance times from 30 to 240 minutes

Nominal rebar diameter	Drill hole diameter	Maximum force in rebar	Anchorage depth	Maximum force in rebar in conjunction with Hilti HIT-RE 500 (yielding point f_{yk} = 500 N/mm²) as a function of fire resistance class					
dia.	D	$F_{s,T}$	L	F30	F60	F90	F120	F180	F240
mm	mm	kN	mm	kN	kN	kN	kN	kN	kN
8	10	16.19	65	1.38	0.57	0.19	0.05	0	0
			80	2.35	1.02	0.47	0.26	0	0
			95	3.87	1.68	0.88	0.55	0.12	0
			115	7.30	3.07	1.71	1.14	0.44	0.18
			150	16.19	8.15	4.59	3.14	1.41	0.80
			180		16.19	9.99	6.75	2.94	1.70
			205			16.19	12.38	5.08	2.86
			220				16.19	6.95	3.82
			265					16.19	8.57
			305						16.19
10	12	25.29	80	2.94	1.27	0.59	0.33	0	0
			100	5.68	2.45	1.31	0.85	0.24	0
			120	10.66	4.44	2.48	1.68	0.68	0.31
			140	17.57	7.76	4.38	2.99	1.33	0.73
			165	25.29	15.06	8.50	5.79	2.58	1.50
			195		25.29	17.63	12.18	5.12	2.93
			220			25.29	20.66	8.69	4.78
			235				25.29	11.80	6.30
			280					25.29	13.86
			320						25.29
12	16	36.42	95	5.80	2.52	1.32	0.83	0.18	0
			120	12.79	5.33	2.97	2.01	0.82	0.37
			145	23.16	10.68	6.02	4.12	1.84	1.03
			180	36.42	24.29	14.99	10.12	4.41	2.55
			210		36.42	27.38	20.65	8.47	4.74
			235			36.42	31.01	14.16	7.56
			250				36.42	19.13	9.89
			295					36.42	21.43
			335						36.42
14	18	49.58	110	10.92	4.65	2.55	1.70	0.61	0.20
			140	24.60	10.87	6.13	4.19	1.86	1.03
			170	39.12	23.50	13.55	9.20	4.07	2.37
			195	49.58	35.60	24.69	17.05	7.17	4.10
			225		49.58	39.20	31.34	13.48	7.34
			250			49.58	43.44	22.32	11.54
			265				49.58	29.49	15.00
			310					49.58	31.98
			350						49.58
16	20	64.75	130	22.59	9.42	5.30	3.61	1.56	0.80
			160	39.17	21.33	11.95	8.15	3.65	2.11
			190	55.76	37.92	25.45	17.25	7.35	4.22
			210	64.75	48.98	36.51	27.53	11.29	6.32
			240		64.75	53.10	44.12	20.88	11.04
			265			64.75	57.94	33.70	17.14
			280				64.75	42.00	22.17
			325					64.75	44.84
			365						64.75

Comments : Intermediate values may be obtained by linear interpolation. Extrapolating is not permitted.

Evaluation of the maximum forces in rebars according to Eurocode 2 – 1992 for a nominal bar diameter from 8 to 16 mm

Materialprüfanstalt für das Bauwesen
Institut für Baustoffe, Massivbau und Brandschutz
Technische Universität Braunschweig

Annex 9 of Test Report No. 3357/0550-5 -Nau- dated July 30, 2002

Maximum connection force of rebar as per Eurocode 2 - 1992 concerning ANCHORING during exposure to fire in relation to fire resistance times from 30 to 240 minutes

Nominal rebar diameter	Drill hole diameter	Maximum force in rebar	Anchorage depth	Maximum force in rebar in conjunction with Hilti HIT-RE 500 (yielding point f_{yk} = 500 N/mm²) as a function of fire resistance class					
dia.	D	$F_{s,T}$	L	F30	F60	F90	F120	F180	F240
mm	mm	kN	mm	kN	kN	kN	kN	kN	kN
20	25	101.18	160	48.97	26.67	14.93	10.18	4.56	2.64
			200	76.61	54.31	38.73	27.50	11.42	6.48
			240	101.18	81.96	66.37	55.15	26.10	13.80
			270		101.18	87.11	75.88	45.58	23.36
			295			101.18	93.16	62.86	35.72
			310				101.18	73.23	45.69
			355					101.18	76.79
			395						101.18
25	30	158.09	200	95.77	67.89	48.41	34.37	14.27	8.10
			250	138.96	111.09	91.60	77.57	39.86	20.61
			275	158.09	132.69	113.20	99.17	61.30	31.81
			305		158.09	139.12	125.09	87.22	52.79
			330			158.09	146.69	108.82	74.39
			345				158.09	121.77	87.34
			390					158.09	126.22
			430						158.09
32	40	259.02	255	183.40	147.72	122.78	104.82	56.35	28.80
			275	205.52	169.84	144.90	126.94	78.46	40.71
			325	259.02	225.13	200.19	182.23	133.75	89.68
			360		259.02	238.89	220.93	172.46	128.39
			380			259.02	243.05	194.58	150.51
			395				259.02	211.16	167.09
			440					259.02	216.86
			480						259.02
36	44	327.82	290	249.87	209.73	181.67	161.46	106.93	59.10
			325	293.41	253.27	225.21	205.01	150.47	100.89
			355	327.82	290.59	262.54	242.33	187.80	138.22
			385		327.82	299.86	279.65	225.12	175.54
			410			327.82	310.75	256.22	206.64
			425				327.82	274.88	225.30
			470					327.82	281.28
			510						327.82
40	47	404.71	320	319.10	274.50	243.33	220.87	160.28	105.19
			355	367.48	322.88	291.71	269.25	208.66	153.57
			385	404.71	364.35	333.18	310.72	250.13	195.04
			415		404.71	374.64	352.19	291.60	236.51
			440			404.71	386.75	326.16	271.07
			455				404.71	346.89	291.80
			500					404.71	354.01
			540						404.71

Comments : Intermediate values may be obtained by linear interpolation. Extrapolating is not permitted.

Evaluation of the maximum forces in rebars according to Eurocode 2 – 1992 for a nominal bar diameter from 20 to 40 mm

Annex 10 of Test Report No. 3357/0550-5 -Nau- dated July 30, 2002

Materialprüfanstalt für das Bauwesen
Institut für Baustoffe, Massivbau und Brandschutz
Technische Universität Braunschweig

Force maximale de ou dans la barre selon NF-ENV 1991-2-2 : 1955-02 (Eurocode 2) sous tenue au feu pour l' ANCRAGE de barres d'armature en fonction des résistances au feu de 30 à 240 minutes

Diamètre nominal du fer HA	Diamètre de forage	Force maximale de barre	Longueur de scellement	Force maximale de barre pour Hilti HIT-RE 500 (limite d'étirage f_{yk} = 500 N/mm²) en fonction des classes de résistance au feu					
dia.	D	$F_{s,T}$	L	F30	F60	F90	F120	F180	F240
mm	mm	kN	mm	daN	daN	daN	daN	daN	daN
8	10	1619	65	138	57	19	5	0	0
			80	235	102	47	26	0	0
			95	387	168	88	55	12	0
			115	730	307	171	114	44	18
			150	1619	815	459	314	141	80
			180		1619	999	675	294	170
			205			1619	1238	508	286
			220				1619	695	382
			265					1619	857
			305						1619
10	12	2529	80	294	127	59	33	0	0
			100	568	245	131	85	24	0
			120	1066	444	248	168	68	31
			140	1757	776	438	299	133	73
			165	2529	1506	850	579	258	150
			195		2529	1763	1218	512	293
			220			2529	2066	869	478
			235				2529	1180	630
			280					2529	1386
			320						2529
12	16	3642	95	580	252	132	83	18	0
			120	1279	533	297	201	82	37
			145	2316	1068	602	412	184	103
			180	3642	2429	1499	1012	441	255
			210		3642	2738	2065	847	474
			235			3642	3101	1416	756
			250				3642	1913	989
			295					3642	2143
			335						3642
14	18	4958	110	1092	465	255	170	61	20
			140	2460	1087	613	419	186	103
			170	3912	2350	1355	920	407	237
			195	4958	3560	2469	1705	717	410
			225		4958	3920	3134	1348	734
			250			4958	4344	2232	1154
			265				4958	2949	1500
			310					4958	3198
			350						4958
16	20	6475	130	2259	942	530	361	156	80
			160	3917	2133	1195	815	365	211
			190	5576	3792	2545	1725	735	422
			210	6475	4898	3651	2753	1129	632
			240		6475	5310	4412	2088	1104
			265			6475	5794	3370	1714
			280				6475	4200	2217
			325					6475	4484
			365						6475

Remarque : Les Valeurs intermédiaires peuvent être obtenues par interpolation linéaire. Extrapolation n'est pas permis.

Evaluation of the maximum forces in rebars according to NF-ENV 1991-2-2 : 1955-02 (Eurocode 2) for a nominal bar diameter from 8 to 16 mm (in French)

Annex 11 of Test Report No. 3357/0550-5 -Nau- dated July 30, 2002

Materialprüfanstalt für das Bauwesen
Institut für Baustoffe, Massivbau und Brandschutz
Technische Universität Braunschweig

Force maximale de ou dans la barre selon NF-ENV 1991-2-2 : 1955-02 (Eurocode 2) sous tenue au feu pour l' ANCRAGE de barres d'armature en fonction des résistances au feu de 30 à 240 minutes

Diamètre nominal du fer HA	Diamètre de forage	Force maximale de barre	Longueur de scellement	Force maximale de barre pour Hilti HIT-RE 500 (limite d'étirage f_{yk} = 500 N/mm²) en fonction des classes de résistance au feu					
dia.	D	$F_{s,T}$	L	F30	F60	F90	F120	F180	F240
mm	mm	kN	mm	daN	daN	daN	daN	daN	daN
20	25	10118	160	4897	2667	1493	1018	456	264
			200	7661	5431	3873	2750	1142	648
			240	10118	8196	6637	5515	2610	1380
			270		10118	8711	7588	4558	2336
			295			10118	9316	6286	3572
			310				10118	7323	4569
			355					10118	7679
			395						10118
25	30	15809	200	9577	6789	4841	3437	1427	810
			250	13896	11109	9160	7757	3986	2061
			275	15809	13269	11320	9917	6130	3181
			305		15809	13912	12509	8722	5279
			330			15809	14669	10882	7439
			345				15809	12177	8734
			390					15809	12622
			430						15809
32	40	25902	255	18340	14772	12278	10482	5635	2880
			275	20552	16984	14490	12694	7846	4071
			325	25902	22513	20019	18223	13375	8968
			360		25902	23889	22093	17246	12839
			380			25902	24305	19458	15051
			395				25902	21116	16709
			440					25902	21686
			480						25902
36	44	32782	290	24987	20973	18167	16146	10693	5910
			325	29341	25327	22521	20501	15047	10089
			355	32782	29059	26254	24233	18780	13822
			385		32782	29986	27965	22512	17554
			410			32782	31075	25622	20664
			425				32782	27488	22530
			470					32782	28128
			510						32782
40	47	40471	320	31910	27450	24333	22087	16028	10519
			355	36748	32288	29171	26925	20866	15357
			385	40471	36435	33318	31072	25013	19504
			415		40471	37464	35219	29160	23651
			440			40471	38675	32616	27107
			455				40471	34689	29180
			500					40471	35401
			540						40471

Remarque : Les Valeurs intermédiaires peuvent être obtenues par interpolation linéaire. Extrapolation n'est pas permis.

Maximum connection force of rebar as per Austrian Standard B 4700 – 2000 concerning ANCHORING during exposure to fire in relation to fire resistance times from 30 to 240 Minutes

Nominal rebar diameter	Drill hole diameter	Maximum force in rebar	Anchorage depth	Maximum force in rebar in conjunction with Hilti HIT-RE 500 (yielding point f_{yk} = 550 N/mm²) as a function of fire resistance class					
dia.	D	$F_{s,T}$	L	F30	F60	F90	F120	F180	F240
mm	mm	kN	mm	kN	kN	kN	kN	kN	kN
8	10	17.81	65	1.38	0.57	0.19	0.05	0	0
			80	2.35	1.02	0.47	0.26	0	0
			95	3.87	1.68	0.88	0.55	0.12	0
			115	7.30	3.07	1.71	1.14	0.44	0.18
			155	17.81	9.33	5.24	3.58	1.61	0.92
			190		17.81	12.73	8.63	3.67	2.11
			210			17.81	13.76	5.65	3.16
			225				17.81	7.70	4.20
			270					17.81	9.34
			310						17.81
10	12	27.82	80	2.94	1.27	0.59	0.33	0	0
			100	5.68	2.45	1.31	0.85	0.24	0
			120	10.66	4.44	2.48	1.68	0.68	0.31
			140	17.57	7.76	4.38	2.99	1.33	0.73
			170	27.82	16.79	9.68	6.57	2.91	1.69
			205		27.82	21.09	15.48	6.35	3.58
			225			27.82	22.39	9.63	5.25
			245				27.82	14.43	7.54
			285					27.82	15.08
			325						27.82
12	16	40.07	95	5.80	2.52	1.32	0.83	0.18	0
			120	12.79	5.33	2.97	2.01	0.82	0.37
			145	23.16	10.68	6.02	4.12	1.84	1.03
			190	40.07	28.44	19.09	12.94	5.51	3.17
			220		40.07	31.53	24.79	10.43	5.73
			245			40.07	35.16	17.31	9.05
			260				40.07	23.20	11.79
			305					40.07	25.34
			345						40.07
14	18	54.54	110	10.92	4.65	2.55	1.70	0.61	0.20
			140	24.60	10.87	6.13	4.19	1.86	1.03
			170	39.12	23.50	13.55	9.20	4.07	2.37
			205	54.54	40.44	29.53	21.67	8.89	5.01
			235		54.54	44.04	36.18	16.52	8.82
			260			54.54	48.28	27.07	13.75
			275				54.54	34.33	17.81
			320					54.54	36.82
			360						54.54
16	20	71.23	130	22.59	9.42	5.30	3.61	1.56	0.80
			160	39.17	21.33	11.95	8.15	3.65	2.11
			190	55.76	37.92	25.45	17.25	7.35	4.22
			220	71.23	54.51	42.04	33.06	13.90	7.64
			255		71.23	61.39	52.41	28.17	14.40
			275			71.23	63.47	39.23	20.36
			290				71.23	47.52	26.26
			335					71.23	50.37
			375						71.23

Comments : Intermediate values may be obtained by linear interpolation. Extrapolating is not permitted.

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Maximum connection force of rebar as per Austrian Standard B 4700 – 2000 concerning ANCHORING during exposure to fire in relation to fire resistance times from 30 to 240 Minutes

Nominal rebar diameter	Drill hole diameter	Maximum force in rebar	Anchorage depth	Maximum force in rebar in conjunction with Hilti HIT-RE 500 (yielding point f_{yk} = 550 N/mm²) as a function of fire resistance class					
dia.	D	$F_{s,T}$	L	F30	F60	F90	F120	F180	F240
mm	mm	kN	mm	kN	kN	kN	kN	kN	kN
20	25	111.30	160	48.97	26.67	14.93	10.18	4.56	2.64
			200	76.61	54.31	38.73	27.50	11.42	6.48
			240	104.26	81.96	66.37	55.15	26.10	13.80
			255	111.30	92.33	76.74	65.51	35.22	18.00
			285		111.30	97.47	86.25	55.95	30.17
			305			111.30	100.07	69.77	42.23
			325				111.30	83.60	56.05
			370					111.30	87.15
			405						111.30
26	34	188.09	210	108.58	79.59	59.33	44.73	18.35	10.26
			260	153.51	124.52	104.25	89.66	50.27	25.54
			300	188.09	160.46	140.19	125.60	86.21	50.49
			335		188.09	171.64	157.05	117.66	81.85
			355			188.09	175.02	135.63	99.82
			370				188.09	149.11	113.30
			415					188.09	153.73
			455						188.09
30	38	250.42	240	156.39	122.94	99.56	82.72	39.16	20.69
			300	218.59	185.14	161.76	144.92	99.48	58.26
			335	250.42	221.43	198.05	181.21	135.76	94.45
			365		250.42	229.15	212.31	166.86	125.55
			390			250.42	238.23	192.78	151.47
			405				250.42	208.33	167.02
			450					250.42	213.67
			490						250.42
36	44	360.60	290	249.87	209.73	181.67	161.46	106.93	59.10
			360	336.96	296.81	268.76	248.55	194.02	144.44
			380	360.60	321.70	293.64	273.43	218.90	169.32
			415		360.60	337.18	316.97	262.44	212.86
			435			360.60	341.86	287.32	237.74
			455				360.60	312.20	262.62
			495					360.60	312.39
			535						360.60
40	47	445.19	320	319.10	274.50	243.33	220.87	160.28	105.19
			400	429.69	385.09	353.91	331.46	270.87	215.78
			415	445.19	405.82	374.64	352.19	291.60	236.51
			445		445.19	416.11	393.66	333.07	277.98
			470			445.19	428.22	367.63	312.54
			485				445.19	388.36	333.27
			530					445.19	395.48
			570						445.19

Comments : Intermediate values may be obtained by linear interpolation. Extrapolating is not permitted.

Evaluation of the maximum forces in rebars according to Austrian Standard B 4700 - 2000 for a nominal bar diameter from 20 to 40 mm	Annex 14 of Test Report No. 3357/0550-5 -Nau-dated July 30, 2002
Materialprüfanstalt für das Bauwesen Institut für Baustoffe, Massivbau und Brandschutz Technische Universität Braunschweig	

Maximum connection force of rebar as per British Standard BS 8110 : 1 – 1997 concerning ANCHORING during exposure to fire in relation to fire resistance times from 30 to 240 Minutes

Nominal rebar diameter	Drill hole diameter	Maximum force in rebar	Anchorage depth	Maximum force in rebar in conjunction with Hilti HIT-RE 500 (yielding point f_{yk} = 460 N/mm²) as a function of fire resistance class					
dia.	D	$F_{s,T}$	L	F30	F60	F90	F120	F180	F240
mm	mm	kN	mm	kN	kN	kN	kN	kN	kN
8	10	15.73	65	1.38	0.57	0.19	0.05	0	0
			80	2.35	1.02	0.47	0.26	0	0
			95	3.87	1.68	0.88	0.55	0.12	0
			115	7.30	3.07	1.71	1.14	0.44	0.18
			150	15.73	8.15	4.59	3.14	1.41	0.80
			180		15.73	9.99	6.75	2.94	1.70
			205			15.73	12.38	5.08	2.86
			220				15.73	6.95	3.82
			265					15.73	8.57
			305						15.73
10	12	24.58	80	2.94	1.27	0.59	0.33	0	0
			100	5.68	2.45	1.31	0.85	0.24	0
			120	10.66	4.44	2.48	1.68	0.68	0.31
			140	17.57	7.76	4.38	2.99	1.33	0.73
			165	24.58	15.06	8.50	5.79	2.58	1.50
			195		24.58	17.63	12.18	5.12	2.93
			220			24.58	20.66	8.69	4.78
			235				24.58	11.80	6.30
			280					24.58	13.86
			320						24.58
12	16	35.39	95	5.80	2.52	1.32	0.83	0.18	0
			120	12.79	5.33	2.97	2.01	0.82	0.37
			145	23.16	10.68	6.02	4.12	1.84	1.03
			175	35.39	22.22	13.20	8.94	3.93	2.28
			210		35.39	27.38	20.65	8.47	4.74
			230			35.39	28.94	12.80	6.90
			250				35.39	19.13	9.89
			290					35.39	19.70
			330						35.39
14	18	48.17	110	10.92	4.65	2.55	1.70	0.61	0.20
			140	24.60	10.87	6.13	4.19	1.86	1.03
			170	39.12	23.50	13.55	9.20	4.07	2.37
			190	48.17	33.18	22.27	15.10	6.43	3.69
			225		48.17	39.20	31.34	13.48	7.34
			245			48.17	41.02	20.20	10.56
			260				48.17	27.07	13.75
			305					48.17	29.56
			345						48.17
16	20	62.92	130	22.59	9.42	5.30	3.61	1.56	0.80
			160	39.17	21.33	11.95	8.15	3.65	2.11
			190	55.76	37.92	25.45	17.25	7.35	4.22
			205	62.92	46.21	33.74	24.76	10.16	5.73
			240		62.92	53.10	44.12	20.88	11.04
			260			62.92	55.17	30.94	15.72
			275				62.92	39.23	20.36
			320					62.92	42.08
			360						62.92

Comments : Intermediate values may be obtained by linear interpolation. Extrapolating is not permitted.

Evaluation of the maximum forces in rebars according to British Standard BS 8110 : 1 - 1997 for a nominal bar diameter from 8 to 16 mm

Annex 15 of Test Report No. 3357/0550-5 -Nau- dated July 30, 2002

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Maximum connection force of rebar as per British Standard BS 8110 : 1 – 1997 concerning ANCHORING during exposure to fire in relation to fire resistance times from 30 to 240 Minutes

Nominal rebar diameter	Drill hole diameter	Maximum force in rebar	Anchorage depth	Maximum force in rebar in conjunction with Hilti HIT-RE 500 (yielding point f_{yk} = 460 N/mm²) as a function of fire resistance class					
dia.	D	$F_{s,T}$	L	F30	F60	F90	F120	F180	F240
mm	mm	kN	mm	kN	kN	kN	kN	kN	kN
20	25	98.31	160	48.97	26.67	14.93	10.18	4.56	2.64
			200	76.61	54.31	38.73	27.50	11.42	6.48
			235	98.31	78.50	62.92	51.69	23.60	12.60
			265		98.31	83.65	72.42	42.13	21.43
			290			98.31	89.70	59.41	32.83
			305				98.31	69.77	42.23
			350					98.31	73.33
			390						98.31
25	30	153.61	200	95.77	67.89	48.41	34.37	14.27	8.10
			250	138.96	111.09	91.60	77.57	39.86	20.61
			270	153.61	128.37	108.88	94.85	56.98	29.19
			300		153.61	134.80	120.77	82.90	48.55
			325			153.61	142.37	104.50	70.07
			340				153.61	117.45	83.02
			385					153.61	121.90
			425						153.61
28	35	192.68	225	131.45	100.23	78.41	62.69	26.96	14.69
			250	155.64	124.42	102.60	86.88	44.64	23.08
			290	192.68	163.12	141.30	125.58	83.17	45.96
			325		192.68	175.17	159.45	117.04	78.47
			345			192.68	178.80	136.39	97.83
			360				192.68	150.90	112.34
			405					192.68	155.88
			445						192.68
32	40	251.67	255	183.40	147.72	122.78	104.82	56.35	28.80
			280	211.05	175.37	150.43	132.47	83.99	44.34
			320	251.67	219.60	194.66	176.70	128.23	84.15
			350		251.67	227.84	209.87	161.40	117.33
			375			251.67	237.52	189.05	144.98
			390				251.67	205.63	161.56
			435					251.67	211.33
			475						251.67
36	44	318.52	290	249.87	209.73	181.67	161.46	106.93	59.10
			320	287.19	247.05	218.99	198.79	144.25	94.67
			350	318.52	284.37	256.32	236.11	181.58	132.00
			380		318.52	293.64	273.43	218.90	169.32
			400			318.52	298.31	243.78	194.20
			420				318.52	268.66	219.08
			465					318.52	275.06
			500						318.52
40	47	393.23	320	319.10	274.50	243.33	220.87	160.28	105.19
			350	360.57	315.97	284.80	262.34	201.75	146.66
			375	393.23	350.53	319.35	296.90	236.31	181.22
			410		393.23	367.73	345.28	284.69	229.60
			430			393.23	372.93	312.33	257.25
			445				393.23	333.07	277.98
			490					393.23	340.18
			530						393.23

Comments : Intermediate values may be obtained by linear interpolation. Extrapolating is not permitted.

Evaluation of the maximum forces in rebars according to British Standard BS 8110 : 1 - 1997 for a nominal bar diameter from 20 to 40 mm

Annex 16 of Test Report No. 3357/0550-5 -Nau- dated July 30, 2002

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Maximum connection force of rebar as per Singapore Standard CP - 65 : 1999 concerning ANCHORING during exposure to fire in relation to fire resistance times from 30 to 240 Minutes

Nominal rebar diameter	Drill hole diameter	Maximum force in rebar	Anchorage depth	Maximum force in rebar in conjunction with Hilti HIT-RE 500 (yielding point f_{yk} = 460 Mpa) as a function of fire resistance class					
dia.	D	$F_{s,T}$	L	F30	F60	F90	F120	F180	F240
mm	mm	kN	mm	kN	kN	kN	kN	kN	kN
8	10	14.36	65	1.38	0.57	0.19	0.05	0	0
			80	2.35	1.02	0.47	0.26	0	0
			95	3.87	1.68	0.88	0.55	0.12	0
			115	7.30	3.07	1.71	1.14	0.44	0.18
			145	14.36	7.12	4.01	2.74	1.23	0.69
			175		14.36	8.80	5.96	2.62	1.52
			200			14.36	11.00	4.57	2.59
			215				14.36	6.27	3.48
			260					14.36	7.86
			300						14.36
10	12	22.44	80	2.94	1.27	0.59	0.33	0	0
			100	5.68	2.45	1.31	0.85	0.24	0
			120	10.66	4.44	2.48	1.68	0.68	0.31
			140	17.57	7.76	4.38	2.99	1.33	0.73
			155	22.44	11.66	6.55	4.47	2.01	1.15
			190		22.44	15.91	10.78	4.59	2.64
			210			22.44	17.21	7.06	3.95
			230				22.44	10.66	5.75
			270					22.44	11.68
			310						22.44
13	18	37.92	105	8.66	3.72	2.02	1.33	0.43	0.09
			130	18.35	7.65	4.31	2.94	1.27	0.65
			155	29.58	15.16	8.51	5.81	2.61	1.50
			175	37.92	24.07	14.30	9.68	4.25	2.47
			210		37.92	29.66	22.37	9.17	5.13
			230			37.92	31.35	13.86	7.48
			245				37.92	18.76	9.81
			290					37.92	21.34
			330						37.92
16	20	57.45	130	22.59	9.42	5.30	3.61	1.56	0.80
			160	39.17	21.33	11.95	8.15	3.65	2.11
			195	57.45	40.69	28.22	19.49	8.20	4.68
			230		57.45	47.57	38.59	17.06	9.20
			250			57.45	49.65	25.51	13.19
			265				57.45	33.70	17.14
			310					57.45	36.55
			350						57.45
20	25	89.76	160	48.97	26.67	14.93	10.18	4.56	2.64
			200	76.61	54.31	38.73	27.50	11.42	6.48
			220	89.76	68.14	52.55	41.32	17.38	9.56
			255		89.76	76.74	65.51	35.22	18.00
			275			89.76	79.34	49.04	25.45
			295				89.76	62.86	35.72
			335					89.76	62.96
			375						89.76

Comments : Intermediate values may be obtained by linear interpolation. Extrapolating is not permitted.

Evaluation of the maximum forces in rebars according to Singapore Standard CP - 65 : 1999 for a nominal bar diameter from 8 to 20 mm

Annex 17 of Test Report No. 3357/0550-5 -Nau- dated July 30, 2002

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Maximum connection force of rebar as per Singapore Standard CP - 65 : 1999 concerning ANCHORING during exposure to fire in relation to fire resistance times from 30 to 240 Minutes

Nominal rebar diameter	Drill hole diameter	Maximum force in rebar	Anchorage depth	Maximum force in rebar in conjunction with Hilti HIT-RE 500 (yielding point f_{yk} = 460 Mpa) as a function of fire resistance class					
dia.	D	$F_{s,T}$	L	F30	F60	F90	F120	F180	F240
mm	mm	kN	mm	kN	kN	kN	kN	kN	kN
22	28	108.61	175	65.27	40.74	24.20	16.38	7.20	4.18
			220	99.48	74.95	57.80	45.45	19.11	10.51
			235	108.61	86.35	69.21	56.86	25.96	13.86
			265		108.61	92.01	79.67	46.34	23.57
			290			108.61	98.67	65.35	36.11
			305				108.61	76.75	46.45
			350					108.61	80.66
			390						108.61
25	30	140.25	200	95.77	67.89	48.41	34.37	14.27	8.10
			250	138.96	111.09	91.60	77.57	39.86	20.61
			255	140.25	115.41	95.92	81.89	44.02	22.50
			285		140.25	121.84	107.81	69.94	37.71
			310			140.25	129.41	91.54	57.11
			325				140.25	104.50	70.07
			370					140.25	108.94
			410						140.25
28	35	175.93	225	131.45	100.23	78.41	62.69	26.96	14.69
			250	155.64	124.42	102.60	86.88	44.64	23.08
			275	175.93	148.61	126.79	111.07	68.65	35.62
			305		175.93	155.81	140.10	97.68	59.12
			330			175.93	164.29	121.87	83.31
			345				175.93	136.39	97.83
			390					175.93	141.37
			430						175.93
32	40	229.79	255	183.40	147.72	122.78	104.82	56.35	28.80
			280	211.05	175.37	150.43	132.47	83.99	44.34
			300	229.79	197.48	172.54	154.58	106.11	62.15
			330		229.79	205.72	187.76	139.28	95.21
			355			229.79	215.40	166.93	122.86
			370				229.79	183.52	139.45
			415					229.79	189.21
			455						229.79
40	47	359.04	320	319.10	274.50	243.33	220.87	160.28	105.19
			335	339.84	295.24	264.06	241.61	181.02	125.93
			350	359.04	315.97	284.80	262.34	201.75	146.66
			385		359.04	333.18	310.72	250.13	195.04
			405			359.04	338.37	277.78	222.69
			420				359.04	298.51	243.42
			465					359.04	305.63
			505						359.04

Comments : Intermediate values may be obtained by linear interpolation. Extrapolating is not permitted.

Evaluation of the maximum forces in rebars according to Singapore Standard CP - 65 : 1999 for a nominal bar diameter from 22 to 40 mm	Annex 18 of Test Report No. 3357/0550-5 -Nau- dated July 30, 2002
Materialprüfanstalt für das Bauwesen Institut für Baustoffe, Massivbau und Brandschutz Technische Universität Braunschweig	

Maximum connection force of rebar as per Australian Standard AS 3600 - 2001 concerning ANCHORING during exposure to fire in relation to fire resistance times from 30 to 240 Minutes (yielding point f_{yk} = 400 Mpa)

Nominal rebar diameter	Drill hole diameter	Maximum force in rebar	Anchorage depth	Maximum force in rebar in conjunction with Hilti HIT-RE 500 (yielding point f_{yk} = 400 Mpa) as a function of fire resistance class					
dia.	D	$F_{s,T}$	L	F30	F60	F90	F120	F180	F240
mm	mm	kN	mm	kN	kN	kN	kN	kN	kN
8	10	12.87	65	1.38	0.57	0.19	0.05	0	0
			80	2.35	1.02	0.47	0.26	0	0
			95	3.87	1.68	0.88	0.55	0.12	0
			115	7.30	3.07	1.71	1.14	0.44	0.18
			140	12.87	6.21	3.50	2.39	1.06	0.59
			170		12.87	7.74	5.26	2.33	1.35
			195			12.87	9.74	4.10	2.34
			210				12.87	5.65	3.16
			255					12.87	7.20
			290						12.87
10	12	20.11	80	2.94	1.27	0.59	0.33	0	0
			100	5.68	2.45	1.31	0.85	0.24	0
			120	10.66	4.44	2.48	1.68	0.68	0.31
			140	17.57	7.76	4.38	2.99	1.33	0.73
			150	20.11	10.19	5.74	3.92	1.76	1.00
			180		20.11	12.49	8.43	3.67	2.13
			205			20.11	15.48	6.35	3.58
			220				20.11	8.69	4.78
			265					20.11	10.71
			305						20.11
12	16	28.95	95	5.80	2.52	1.32	0.83	0.18	0
			120	12.79	5.33	2.97	2.01	0.82	0.37
			145	23.16	10.68	6.02	4.12	1.84	1.03
			160	28.95	16.00	8.96	6.11	2.74	1.58
			195		28.95	21.16	14.62	6.15	3.51
			215			28.95	22.72	9.40	5.21
			235				28.95	14.16	7.56
			275					28.95	15.27
			315						28.95
16	20	51.47	130	22.59	9.42	5.30	3.61	1.56	0.80
			160	39.17	21.33	11.95	8.15	3.65	2.11
			185	51.47	35.16	22.69	15.26	6.58	3.80
			215		51.47	39.27	30.29	12.53	6.95
			240			51.47	44.12	20.88	11.04
			255				51.47	28.17	14.40
			300					51.47	31.07
			340						51.47
20	25	80.42	160	48.97	26.67	14.93	10.18	4.56	2.64
			200	76.61	54.31	38.73	27.50	11.42	6.48
			210	80.42	61.22	45.64	34.41	14.11	7.89
			240		80.42	66.37	55.15	26.10	13.80
			265			80.42	72.42	42.13	21.43
			280				80.42	52.49	27.71
			325					80.42	56.05
			365						80.42

Comments : Intermediate values may be obtained by linear interpolation. Extrapolating is not permitted.

Evaluation of the maximum forces in rebars according to Australian Standard AS 3600 - 2001 for a nominal bar diameter from 8 to 20 mm (f_{yk} = 400 Mpa)

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Institut für Baustoffe, Massivbau und Brandschutz
Technische Universität Braunschweig

Annex 19
of
Test Report
No. 3357/0550-5 -Nau-
dated
July 30, 2002

Maximum connection force of rebar as per Australian Standard AS 3600 - 2001 concerning ANCHORING during exposure to fire in relation to fire resistance times from 30 to 240 Minutes (yielding point f_{yk} = 400 Mpa)

Nominal rebar diameter	Drill hole diameter	Maximum force in rebar	Anchorage depth	Maximum force in rebar in conjunction with Hilti HIT-RE 500 (yielding point f_{yk} = 400 Mpa) as a function of fire resistance class					
dia.	D	$F_{s,T}$	L	F30	F60	F90	F120	F180	F240
mm	mm	kN	mm	kN	kN	kN	kN	kN	kN
22	28	97.31	175	65.27	40.74	24.20	16.38	7.20	4.18
			200	84.27	59.74	42.60	30.25	12.56	7.13
			220	97.31	74.95	57.80	45.45	19.11	10.51
			250		97.31	80.61	68.26	35.07	18.13
			275			97.31	87.27	53.94	27.99
			290				97.31	65.35	36.11
			335					97.31	69.26
			375						97.31
25	30	125.66	200	95.77	67.89	48.41	34.37	14.27	8.10
			220	113.05	85.17	65.69	51.65	21.72	11.94
			235	125.66	98.13	78.64	64.61	29.50	15.76
			270		125.66	108.88	94.85	56.98	29.19
			290			125.66	112.13	74.26	41.04
			310				125.66	91.54	57.11
			350					125.66	91.66
			390						125.66
28	35	157.63	225	131.45	100.23	78.41	62.69	26.96	14.69
			240	145.96	114.74	92.92	77.20	36.55	19.31
			255	157.63	129.26	107.43	91.72	49.30	25.20
			285		157.63	136.46	120.75	78.33	42.24
			310			157.63	144.94	102.52	63.96
			325				157.63	117.04	78.47
			370					157.63	122.02
			410						157.63
32	40	205.89	255	183.40	147.72	122.78	104.82	56.35	28.80
			265	194.46	158.78	133.84	115.88	67.40	34.28
			280	205.89	175.37	150.43	132.47	83.99	44.34
			310		205.89	183.60	165.64	117.17	73.10
			335			205.89	193.29	144.81	100.74
			350				205.89	161.40	117.33
			395					205.89	167.09
			435						205.89
40	47	321.70	320	319.10	274.50	243.33	220.87	160.28	105.19
			325	321.70	281.41	250.24	227.79	167.19	112.11
			355		321.70	291.71	269.25	208.66	153.57
			380			321.70	303.81	243.22	188.13
			395				321.70	263.95	208.87
			440					321.70	271.07
			480						321.70

Comments : Intermediate values may be obtained by linear interpolation. Extrapolating is not permitted.

Evaluation of the maximum forces in rebars according to Australian Standard AS 3600 - 2001 for a nominal bar diameter from 22 to 40 mm (f_{yk} = 400 Mpa)

Materialprüfanstalt für das Bauwesen
Institut für Baustoffe, Massivbau und Brandschutz
Technische Universität Braunschweig

Annex 20 of Test Report No. 3357/0550-5 -Nau- dated July 30, 2002

Maximum connection force of rebar as per Australian Standard AS 3600 - 2001 concerning ANCHORING during exposure to fire in relation to fire resistance times from 30 to 240 Minutes (yielding point f_{yk} = 500 Mpa)

Nominal rebar diameter	Drill hole diameter	Maximum force in rebar	Anchorage depth	Maximum force in rebar in conjunction with Hilti HIT-RE 500 (yielding point f_{yk} = 500 Mpa) as a function of fire resistance class					
dia.	D	$F_{s,T}$	L	F30	F60	F90	F120	F180	F240
mm	mm	kN	mm	kN	kN	kN	kN	kN	kN
8	10	16.08	65	1.38	0.57	0.19	0.05	0	0
			80	2.35	1.02	0.47	0.26	0	0
			95	3.87	1.68	0.88	0.55	0.12	0
			115	7.30	3.07	1.71	1.14	0.44	0.18
			150	16.08	8.15	4.59	3.14	1.41	0.80
			180		16.08	9.99	6.75	2.94	1.70
			205			16.08	12.38	5.08	2.86
			220				16.08	6.95	3.82
			265					16.08	8.57
			305						16.08
10	12	25.13	80	2.94	1.27	0.59	0.33	0	0
			100	5.68	2.45	1.31	0.85	0.24	0
			120	10.66	4.44	2.48	1.68	0.68	0.31
			140	17.57	7.76	4.38	2.99	1.33	0.73
			165	25.13	15.06	8.50	5.79	2.58	1.50
			195		25.13	17.63	12.18	5.12	2.93
			220			25.13	20.66	8.69	4.78
			235				25.13	11.80	6.30
			295					25.13	17.86
			320						25.13
12	16	36.19	95	5.80	2.52	1.32	0.83	0.18	0
			120	12.79	5.33	2.97	2.01	0.82	0.37
			145	23.16	10.68	6.02	4.12	1.84	1.03
			180	36.19	24.29	14.99	10.12	4.41	2.55
			210		36.19	27.38	20.65	8.47	4.74
			235			36.19	31.01	14.16	7.56
			250				36.19	19.13	9.89
			295					36.19	21.43
			335						36.19
16	20	64.34	130	22.59	9.42	5.30	3.61	1.56	0.80
			160	39.17	21.33	11.95	8.15	3.65	2.11
			190	55.76	37.92	25.45	17.25	7.35	4.22
			210	64.34	48.98	36.51	27.53	11.29	6.32
			240		64.34	53.10	44.12	20.88	11.04
			265			64.34	57.94	33.70	17.14
			280				64.34	42.00	22.17
			325					64.34	44.84
			365						64.34
20	25	100.53	160	48.97	26.67	14.93	10.18	4.56	2.64
			200	76.61	54.31	38.73	27.50	11.42	6.48
			235	100.53	78.50	62.92	51.69	23.60	12.60
			270		100.53	87.11	75.88	45.58	23.36
			290			100.53	89.70	59.41	32.83
			310				100.53	73.23	45.69
			350					100.53	73.33
			390						100.53

Comments : Intermediate values may be obtained by linear interpolation. Extrapolating is not permitted.

Evaluation of the maximum forces in rebars according to Australian Standard AS 3600 - 2001 for a nominal bar diameter from 8 to 20 mm (f_{yk} = 500 Mpa)

Annex 21 of Test Report No. 3357/0550-5 -Nau- dated July 30, 2002

Materialprüfanstalt für das Bauwesen
Institut für Baustoffe, Massivbau und Brandschutz
Technische Universität Braunschweig

Maximum connection force of rebar as per Australian Standard AS 3600 - 2001 concerning ANCHORING during exposure to fire in relation to fire resistance times from 30 to 240 Minutes (yielding point f_{yk} = 500 Mpa)

Nominal rebar diameter	Drill hole diameter	Maximum force in rebar	Anchorage depth	Maximum force in rebar in conjunction with Hilti HIT-RE 500 (yielding point f_{yk} = 500 Mpa) as a function of fire resistance class					
dia.	D	$F_{s,T}$	L	F30	F60	F90	F120	F180	F240
mm	mm	kN	mm	kN	kN	kN	kN	kN	kN
22	28	121.64	175	65.27	40.74	24.20	16.38	7.20	4.18
			220	99.48	74.95	57.80	45.45	19.11	10.51
			250	121.64	97.76	80.61	68.26	35.07	18.13
			285		121.64	107.22	94.87	61.55	33.19
			305			121.64	110.08	76.75	46.45
			325				121.64	91.96	61.66
			365					121.64	92.07
			405						121.64
25	30	157.08	200	95.77	67.89	48.41	34.37	14.27	8.10
			250	138.96	111.09	91.60	77.57	39.86	20.61
			275	157.08	132.69	113.20	99.17	61.30	31.81
			305		157.08	139.12	125.09	87.22	52.79
			330			157.08	146.69	108.82	74.39
			345				157.08	121.77	87.34
			390					157.08	126.22
			430						157.08
28	35	197.04	225	131.45	100.23	78.41	62.69	26.96	14.69
			250	155.64	124.42	102.60	86.88	44.64	23.08
			295	197.04	167.96	146.14	130.42	88.01	50.00
			330		197.04	180.00	164.29	121.87	83.31
			350			197.04	183.64	141.23	102.66
			365				197.04	155.74	117.18
			410					197.04	160.72
			450						197.04
32	40	257.36	255	183.40	147.72	122.78	104.82	56.35	28.80
			280	211.05	175.37	150.43	132.47	83.99	44.34
			325	257.36	225.13	200.19	182.23	133.75	89.68
			355		257.36	233.37	215.40	166.93	122.86
			380			257.36	243.05	194.58	150.51
			395				257.36	211.16	167.09
			440					257.36	216.86
			480						257.36
40	47	402.12	320	319.10	274.50	243.33	220.87	160.28	105.19
			350	360.57	315.97	284.80	262.34	201.75	146.66
			385	402.12	364.35	333.18	310.72	250.13	195.04
			415		402.12	374.64	352.19	291.60	236.51
			435			402.12	379.84	319.25	264.16
			455				402.12	346.89	291.80
			495					402.12	347.10
			535						402.12

Comments : Intermediate values may be obtained by linear interpolation. Extrapolating is not permitted.

Evaluation of the maximum forces in rebars according to Australian Standard AS 3600 - 2001 for a nominal bar diameter from 22 to 40 mm (f_{yk} = 500 Mpa)

Annex 22 of Test Report No. 3357/0550-5 -Nau- dated July 30, 2002

Materialprüfanstalt für das Bauwesen
Institut für Baustoffe, Massivbau und Brandschutz
Technische Universität Braunschweig

MPA Braunschweig · Beethovenstr. 52 · D-38106 Braunschweig

Hilti Entwicklungsgesellschaft mbH
Business Unit Chemie
Herrn Manfred Hartmann
Hiltistr. 6

D- 86916 Kaufering

Schreiben 10608/2004 (093/04)

Unser Zeichen: (3803/1094)-CM
Kunden-Nr.: 6547
Sachbearbeiter: Maertins
Abteilung: BS
Tel. Durchwahl: -8265

Ihre Zeichen: Hr. Hartmann
Ihre Nachricht vom: 07-09-2004

Datum: 05-10-2004

Test Report No. 3357/0550-5 -Nau- dd. 30-07-2002 regarding the fire behavior of reinforcing steel bars (rebar) of the BSt 500 Grade, diameters 8 mm to 40 mm with Hilti Injunktion Mortar HIT-RE 500

Supplement information to the above referenced test report with reference to the temperature distribution of concrete slaps and walls which are exposed to fire on one-side (figure 4; from the Test Report 3357/0550-5 -Nau- dd. 30-07-2002)

Dear Mr. Hartmann,

with reference to the e-mail of 07-09-2004 we Supplemental to the Test Report 3357/0550-5 -Nau- dd. 30-07-2002 , we hereby state that the temperature distribution for one-sided fire loading of concrete slaps and walls for the duration fire from 30 minutes up to 240 minutes that are set on the safe side are provided in Figure 1 on the following page.

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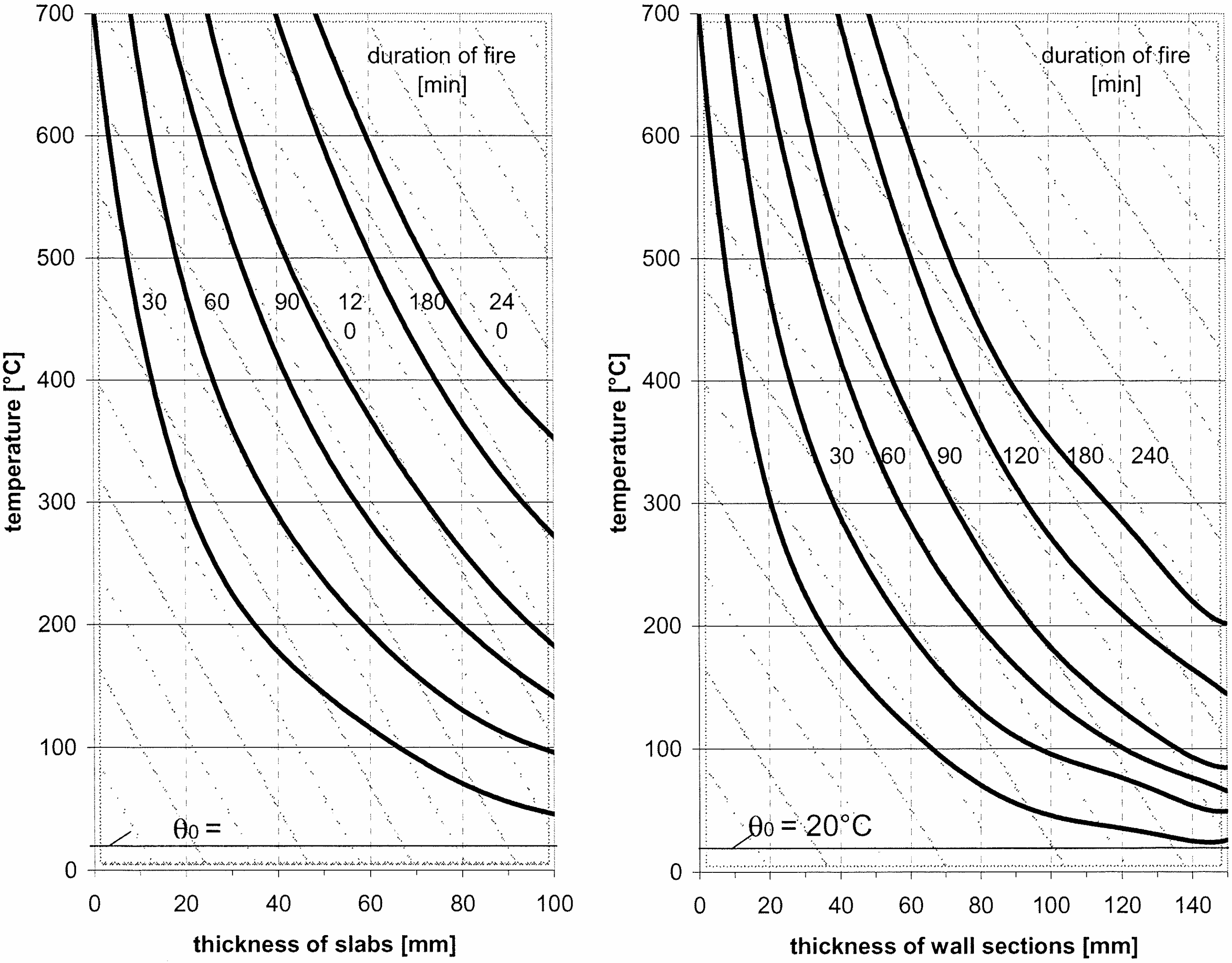
USt.-ID-Nr. MPA-DE 183500654

Using the knowledge about the heat-up thermal behaviour of concrete as per [1] and further experiences from testing and simulations (see fig. 1), the design curve from fig. 3 (see Test Report No. 3357/0550-5 -Nau- dd. 30-07-2002) as well as further experiences from testing normal concrete with quarzitic aggregates, critical temperature-dependent bond stresses, τ_{critT}, can be provided on the safe side in table 3 (see Test Report No. 3357/0550-5 -Nau- dd. 30-07-2002) in relation to the respective concrete coverage, c, for a fire resistance time of 30 to 240 minutes.

<u>Fig. 1:</u> **Temperature distribution as per DIN 4102-2 : 1977-09 (ISO 834) in slabs and wall sections of normal concrete with quarzitic aggregates exposed to fire on one side; from [4], page 141**



Spacial notes

The validity of this letter ends with the validity of the Test Report No. 3357/0550-5 -Nau- dd. 30-07-2002 .

The letter mentioned in conjunction with the Test Report No. 3357/0550-5 -Nau- dd. 30-07-2002 does not replace a general building test certificate.

i.A.
RR Dipl.-Ing. Nause
Deputy Head of Department

i.A.
Dipl.-Ing. Maertins
Engineer in charge

[1] (concrete-fire protection manual) Prof. Dr.Ing. Dr.-Ing. H.c. K. Kordina and Dr.-Ing. C. Meyer-Ottens, issue 19