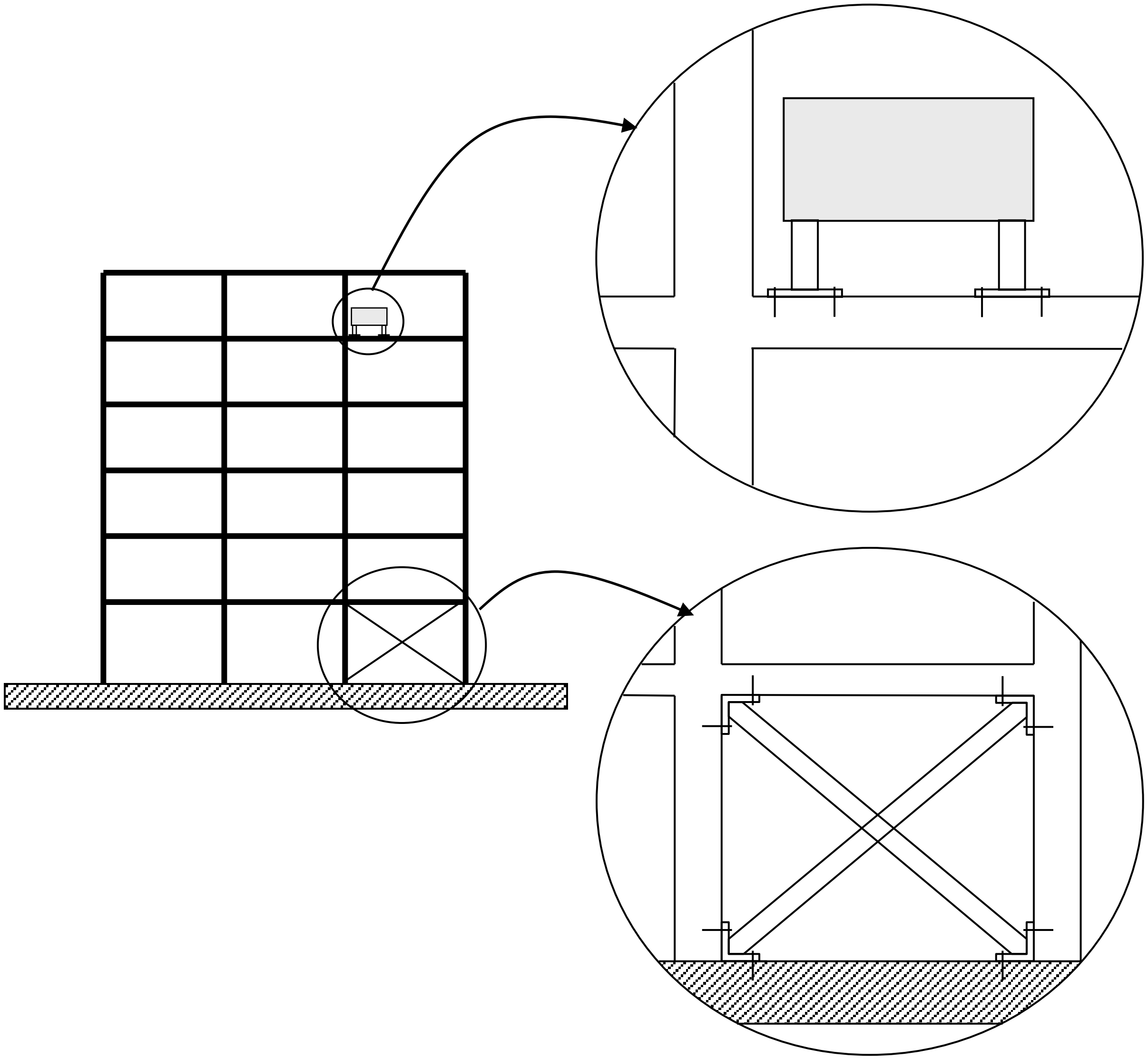
Modern Fixing Technology

State-of-the-Art

fischer
GROUP OF COMPANIES

Fastenings are used for both structural and nonstructural applications



Nonstructural

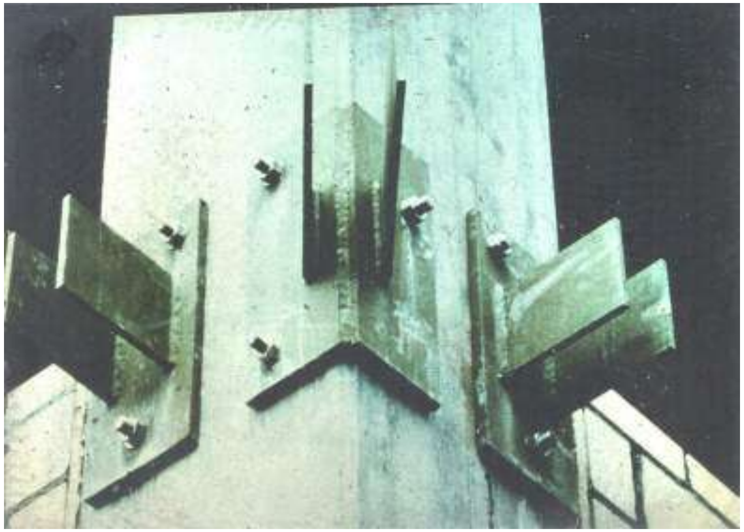
- Facades
- Suspended ceilings
- Heating & ventilation
- Pipelines
- Mechanical equip.
- Etc.

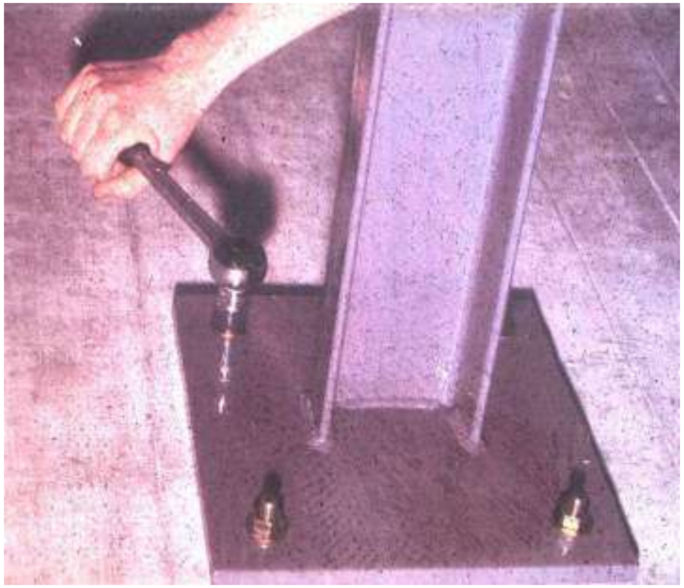
Structural

- Structural connections
- Strengthening


500 kg

Beam Bearings and Column Base Plates





Bridge Footings

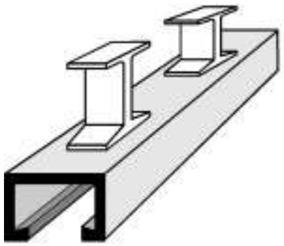
Fastening in Powerplant

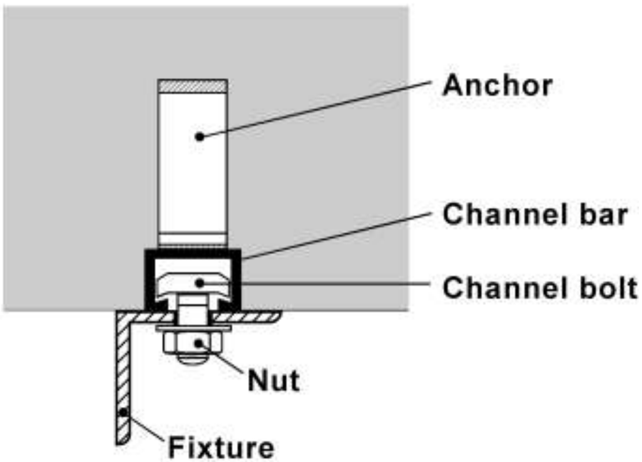
Quelle: P. Carrato, Bechtel

Seismic retrofitting

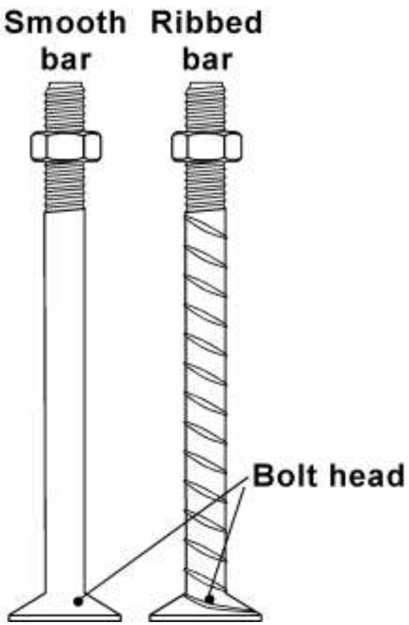
Typical cast-in-place systems are channel bars and headed anchors.

Channel bars

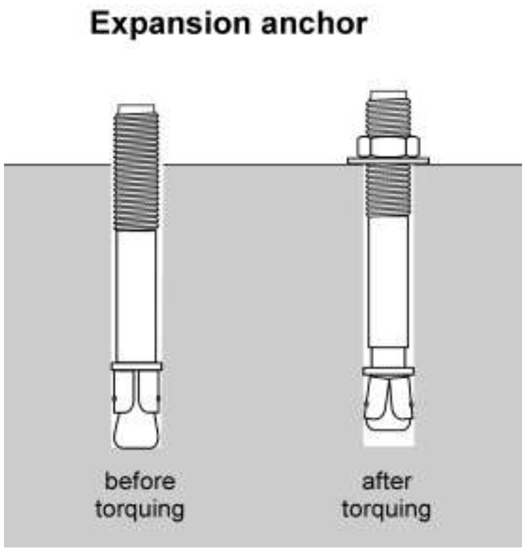


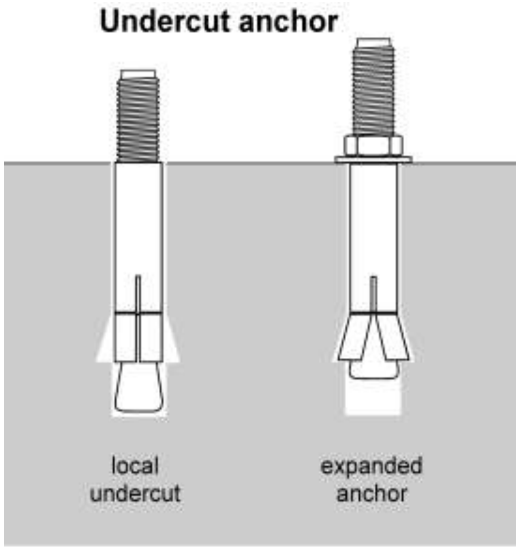


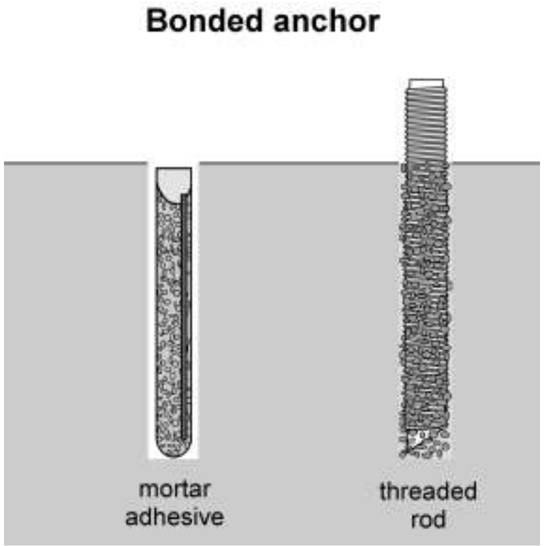
Headed anchors



Cast-in-place anchors transfer tension load mainly by mechanical interlock.







Expansion anchors transfer tension load to the concrete mainly by friction.

Undercut anchors transfer tension load mainly through mechanical interlock.

Bonded anchors transfer tension load by bond stresses.

Bonded expansion anchors

- combination of bond and friction to transfer tension loads
- work well in cracked concrete

Concrete screws

- load transfer is by mechanical interlock
- simple installation

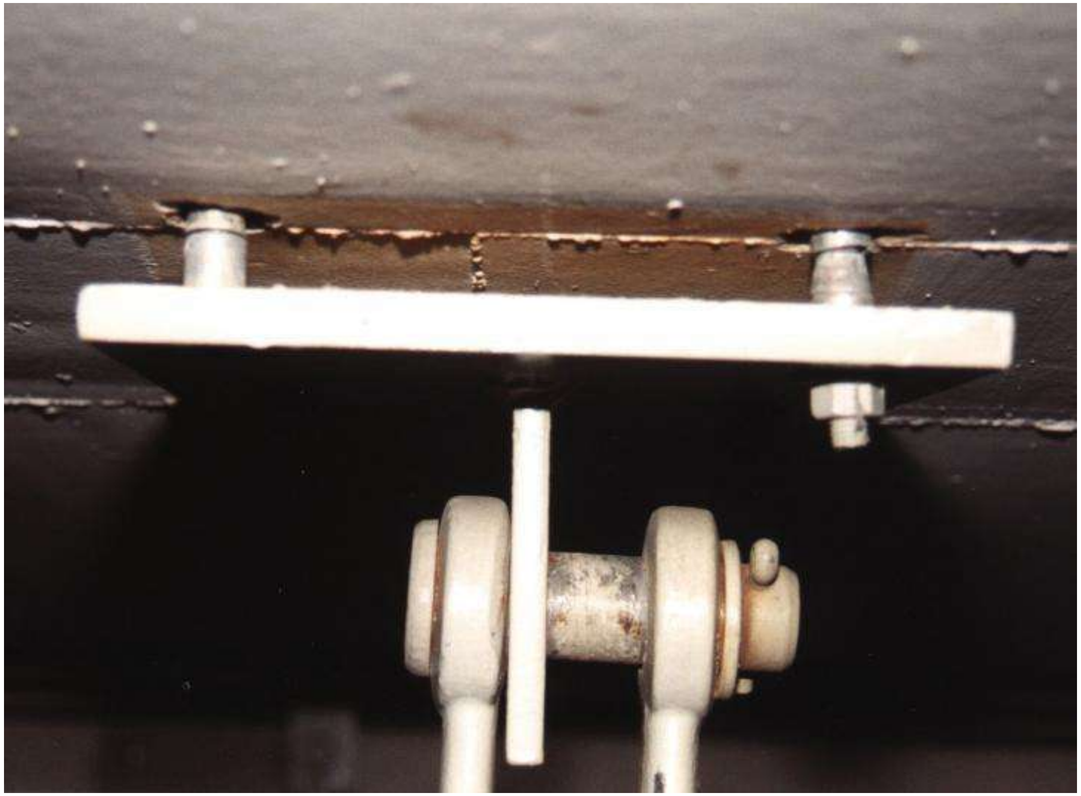
Rail and balustarde -

Problem:

small edge distances causes concrete edge failure

Wrong installitions should be avoided by better training (certification) of the installer and proper supervision

- damaged group with 4 anchors
- after failure of the first anchor, overloading of the neighboring anchor

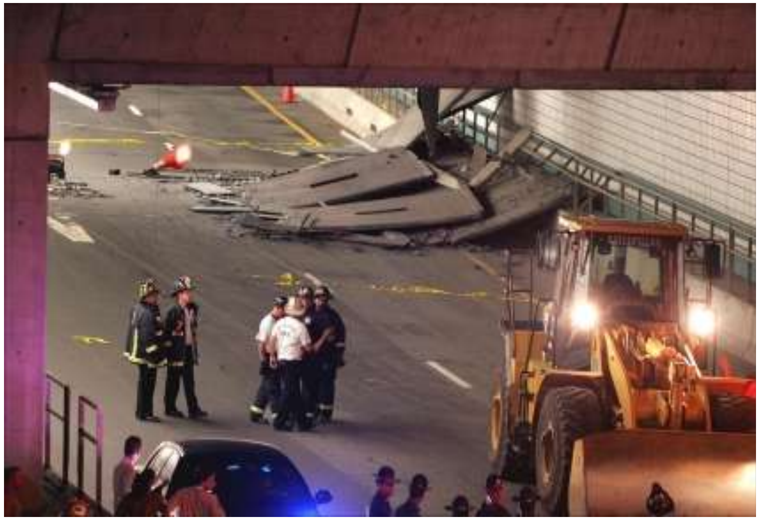


Problem:

small spacing distances will reduce the load capacity – concrete failure will occure (prayout)

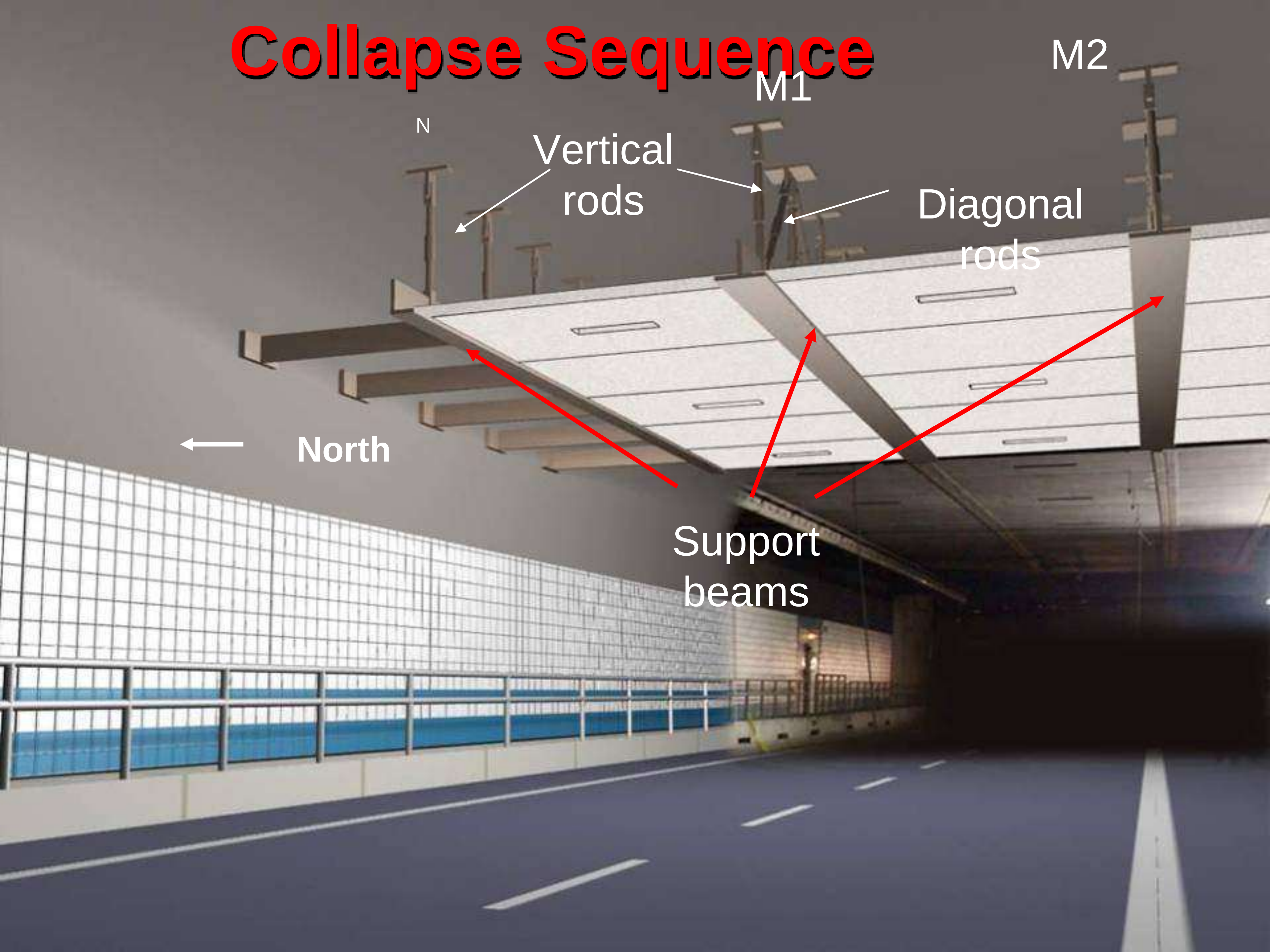
Boston tunnel

- On July 10, 2006 concrete ceiling tiles in the Interstate 90 tunnel fell on a car killing one person and injuring another.

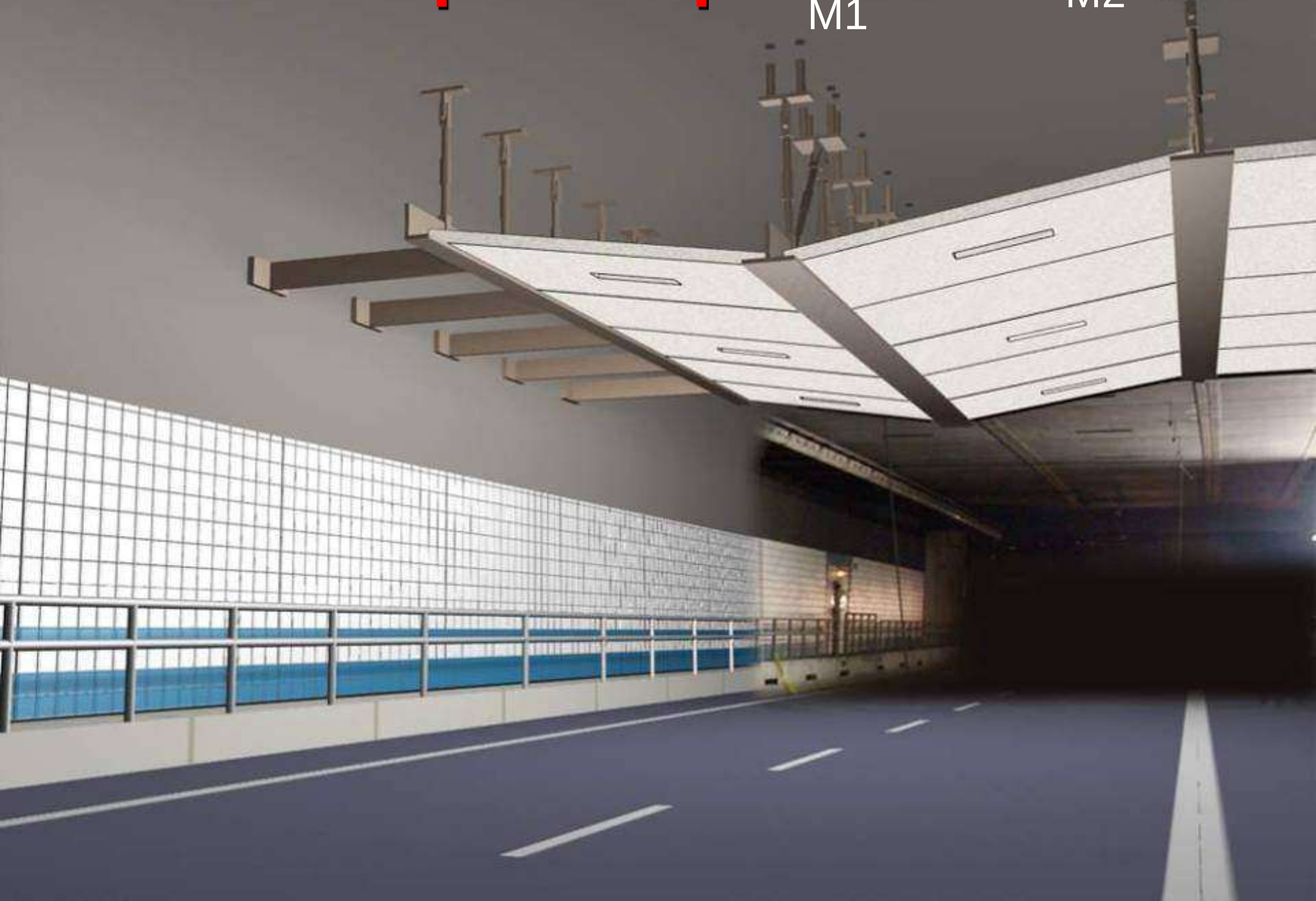



52V T10

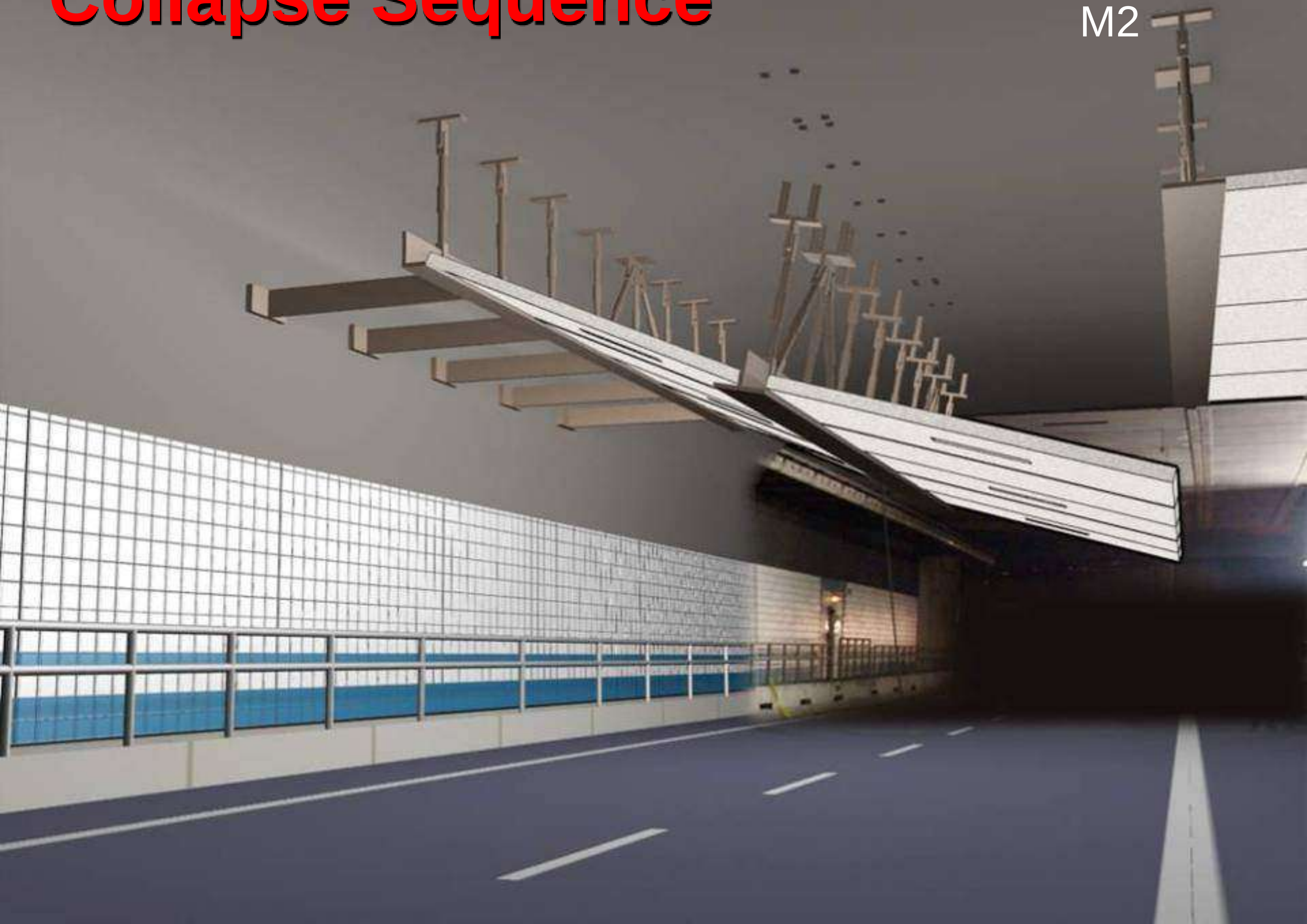
Collapse Sequence



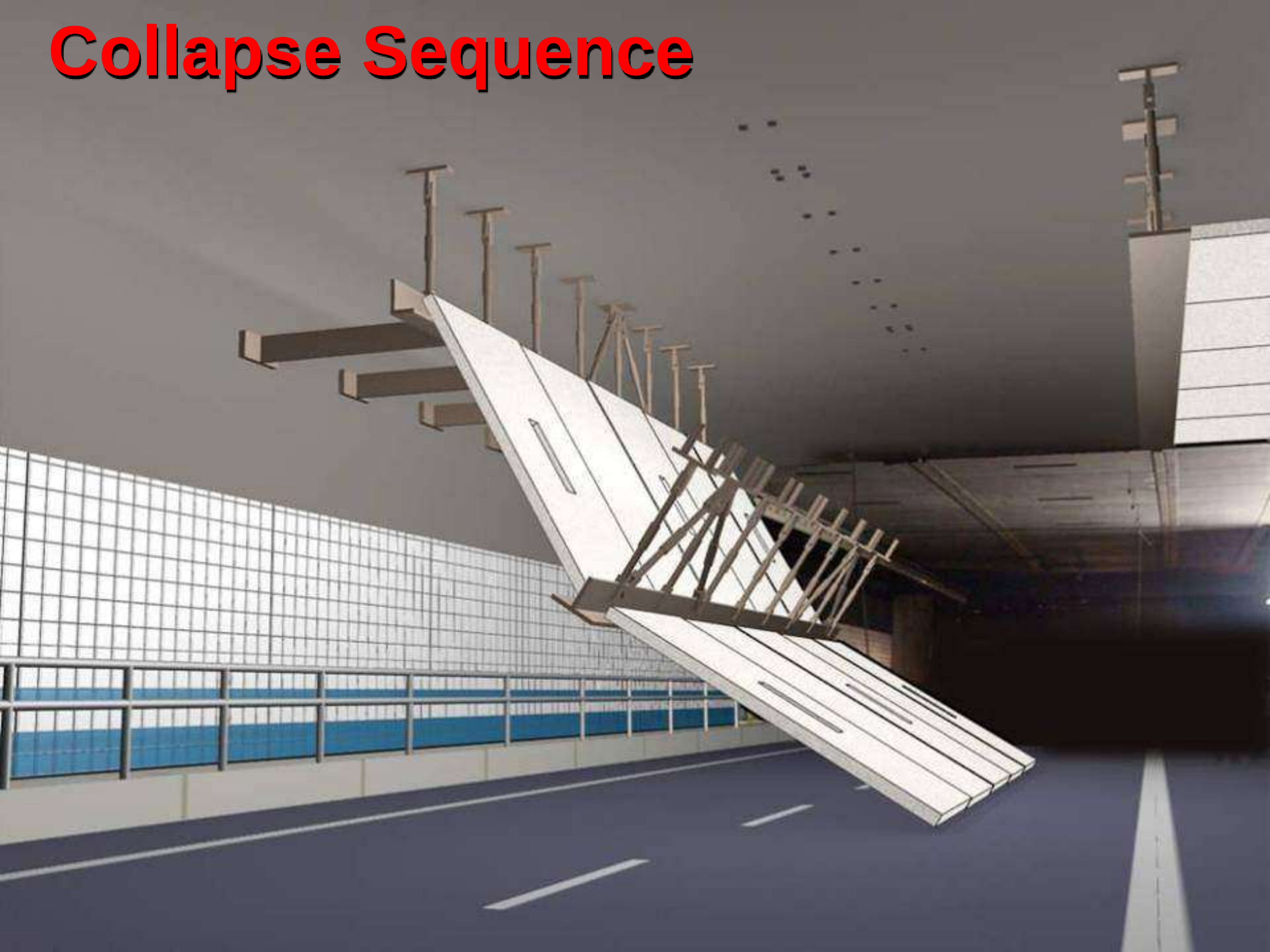
Collapse Sequence



Collapse Sequence



Collapse Sequence



Pull out test on site

Pull out test‘s on site are a common practice

but

Pull out test‘s are not replacing a proper anchor or rebar design!

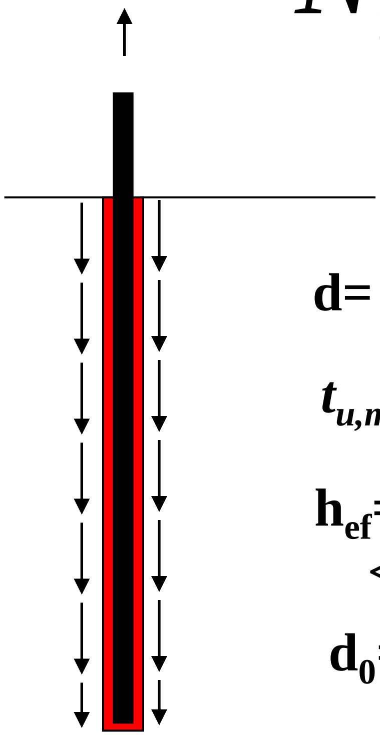
Especially rebar pull out test are misleading!
- single rebar's!
- no test of the full system!
- with shallow embedment depth - ultimate loads can be easily reached!

Pull out tests are essential:
- To verify the anchor behavior in unknown building materials (e.g. masonry and concrete with unknown compressive strength)
- Check of workmanship

Recommended or Design Loads can be calculated from these tests!

NEVER USE THE ULTIMATE TEST VALUES FOR DESIGN

$N_{u,Bond}$



$$N_{u,Bond} = \pi \cdot d \cdot h_{ef} \cdot \tau_{u,m} \quad [N]$$

$$d_0 / d \leq 1{,}5$$

d= diameter of the anchor rod [mm]

$t_{u,m}$= average bond resistance [N/mm²]

h_{ef}= embedment depth [mm]
< 20d

d_0= diameter of of borehole [mm]

Prediction of mean failure load

Design example:
T16
Yield strength 460N/mm^2 (design load 80.4kN)
Ultimate bond strength – 18N/mm^2

Design with ultimate bond strength:

$$h_{ef} = \frac{N_{Rd,s}}{\pi * d * f_b} = \frac{80.4kN}{\pi * 16mm * 18N/mm^2} = 89mm$$

5.6xd

Design with design bond strength:

$$h_{ef} = \frac{N_{Rd,s}}{\pi * d * f_b} = \frac{80.4kN}{\pi * 16mm * 7.7N/mm^2} = 208mm$$

13xd

Design according EC2

$$h_{ef} = \frac{N_{Rd,s}}{\pi * d * f_b} = \frac{80.4kN}{\pi * 16mm * 2.3N/mm^2} = 695mm$$

43xd

fischer FIXING SYSTEMS

Fasteners must function properly in the required application.

Pre-qualification testing is necessary

- check of suitability of anchors

- evaluation of allowable conditions of use

European Organisation for Technical Approval [ETAG 001 (1997)]

American Concrete Institute [ACI 355.2 (2001)]

EOTA

aci international

Tested Quality

Institutions

EOTA

European Organisation for Technical Approvals

ETAG

European Technical Approval Guideline
- Test
- Design

European Technical Approval - Option 1 for Cracked Concrete

European Technical Approval

ETAG 001- Metal Anchors for use in Concrete

Part 1	- anchors in general
Part 2	- torque-controlled expansion anchors
Part 3	- undercut anchors
Part 4	- deformation-controlled expansion anchors
Part 5	- bonded anchors
Part 6	- anchors for lightweight systems
Annex A	- details of tests
Annex B	- tests for admissible service conditions detailed information
Annex C	- design methods for anchorages

+ Comprehension Documents/Technical Reports

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Authorised and notified according to Article 10 of the Council Directive of 21 December 1988 on the approximation of laws, regulations and administrative provisions of Member States relating to construction products (89/106/EEC)

DIBt

Mitglied der EOTA
Member of EOTA

European Technical Approval ETA-05/0164

English translation prepared by DIBt - Original version in German language

Handelsbezeichnung *Trade name*	fischer Highbond-Anker FHB II *fischer Highbond-Anchor FHB II*
Zulassungsinhaber *Holder of approval*	fischerwerke Artur Fischer GmbH & Co. KG Otto-Hahn-Str. 15 79211 Denzlingen
Zulassungsgegenstand und Verwendungszweck *Generic type and use of construction product*	Kraftkontrolliert spreizender Verbunddübel mit Ankerstange aus galvanisch verzinktem Stahl in den Größen M8, M10, M12, M16, M20 und M24 zur Verankerung im Beton *Torque controlled bonded anchor with anchor rod made of galvanised steel of sizes M8, M10, M12, M16, M20 and M24 for use in concrete*
Geltungsdauer: vom *Validity: from*	7. September 2005
bis *to*	7. September 2010
Herstellwerke *Manufacturing plants*	fischerwerke Herstellwerke 1 und 2, Deutschland fischerwerke Herstellwerk 3, Tschechien

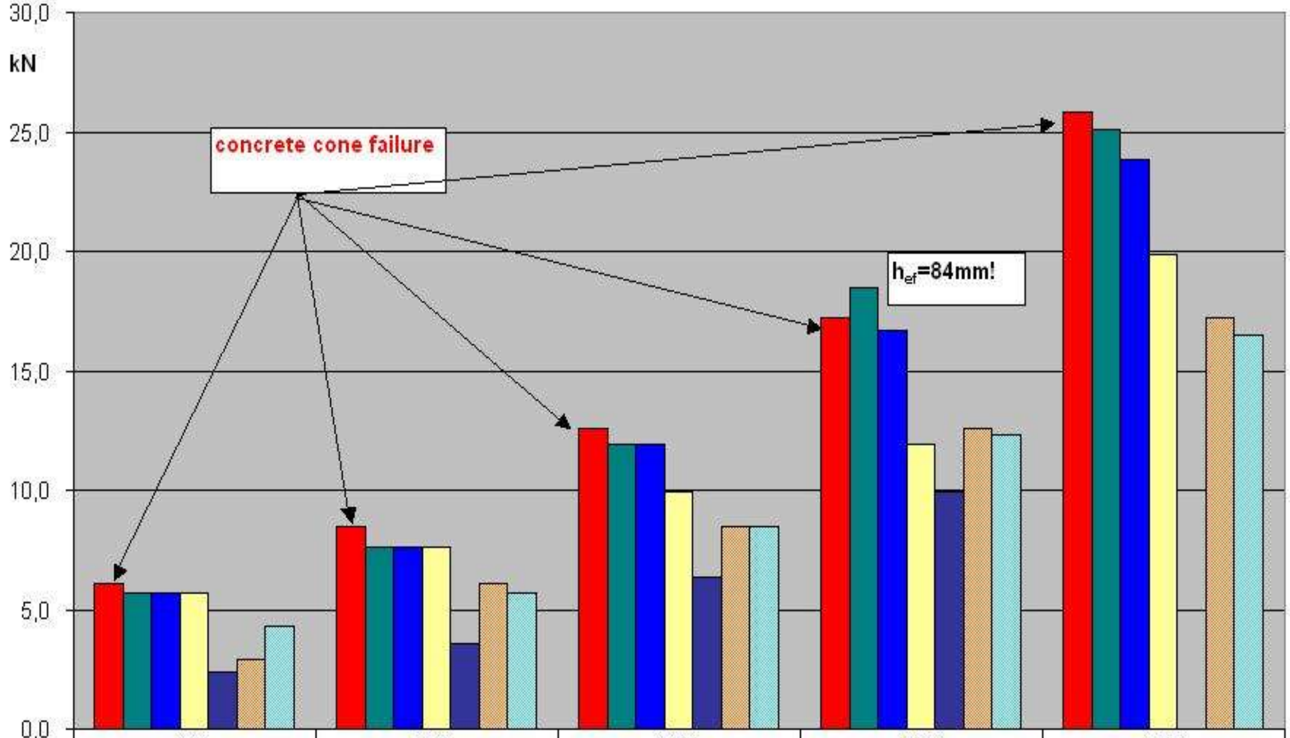
Diese Zulassung umfasst *This Approval contains*	17 Seiten einschließlich 9 Anhänge *17 pages including 9 annexes*

EOTA

Europäische Organisation für Technische Zulassungen
European Organisation for Technical Approvals

Comparison of tensile load bearing cpacity N_{zul}

Single anchor without edge influence in non-cracked concrete C20/25



	M8	M10	M12	M16	M20
fischer FBN II	6,1	8,5	12,6	17,2	25,8
competitor1	5,7	7,6	11,9	18,5	25,1
competitor2	5,7	7,6	11,9	16,7	23,8
competitor3	5,7	7,6	9,9	11,9	19,8
competitor4	2,4	3,6	6,3	9,9	
competitor5	2,9	6,1	8,5	12,6	17,2
competitor6	4,3	5,7	8,5	12,3	16,5

Approvals:

In many countries approvals are no topic.

That´s a failure because approvals guarantee:

- Highest safety standard because of the lots of tests which are required to get an approval
- Constant controll of production

They show quality !

Europäische Technische Zulassung – Option 1 für gerissenen Beton

ALLGEMEINE BAUAUFSICHTLICHE CC-ZULASSUNG mit charakteristischen Tragfähigkeiten und Teilsicherheitsbeiwerten

Schock approval by the Federal Office for Civil Defence, Bonn

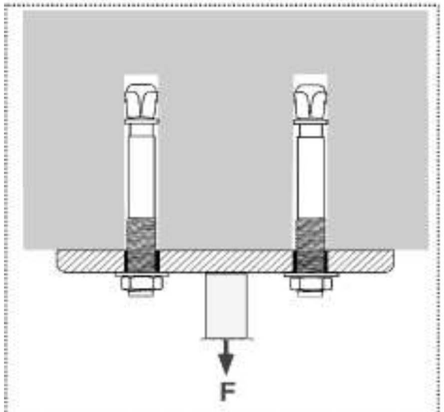
FM APPROVED ab M10

Feuerwiderstandsklasse F 120 Dübelgrößen siehe Prüfbericht

VdS

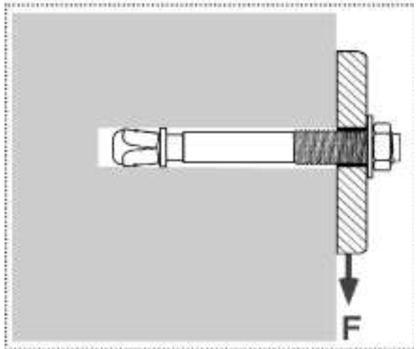
Load Directions and Failure Modes

Tension Loading

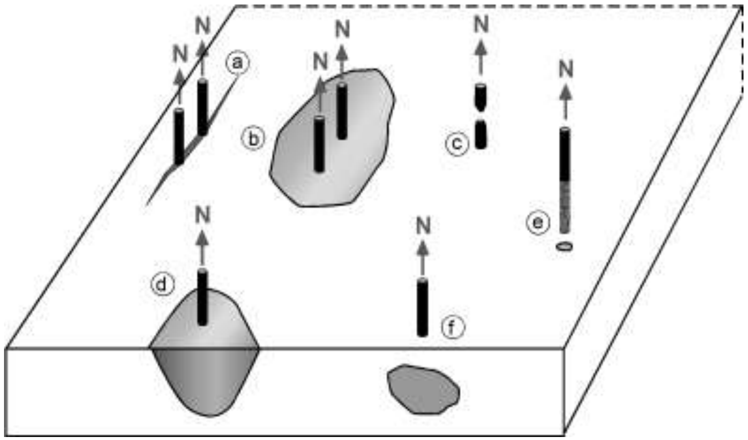


FAILURE MODES
- Splitting (a)
- Concrete Failure (b), (d)
- Steel Failure (c)
- Pull-out and Pull-through (e)
- Blow-out (f)

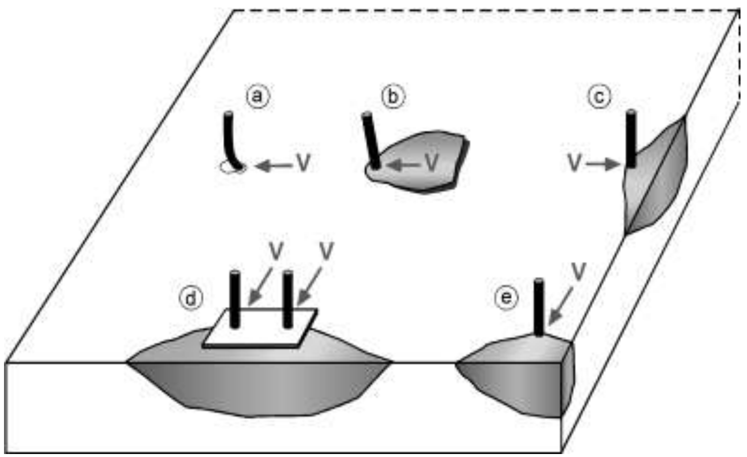
Shear Loading



FAILURE MODES
- Steel Failure (a)
- Concrete Pry-out (b)
- Concrete Failure at the Edge and Corner (c),(d),(e)

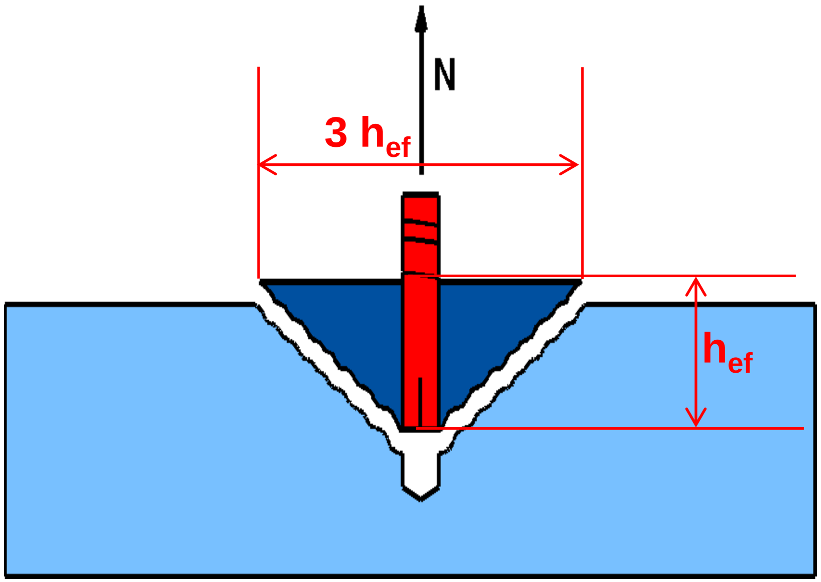


Failure under tension load



Failure under shear load

Break-out body under tensile load



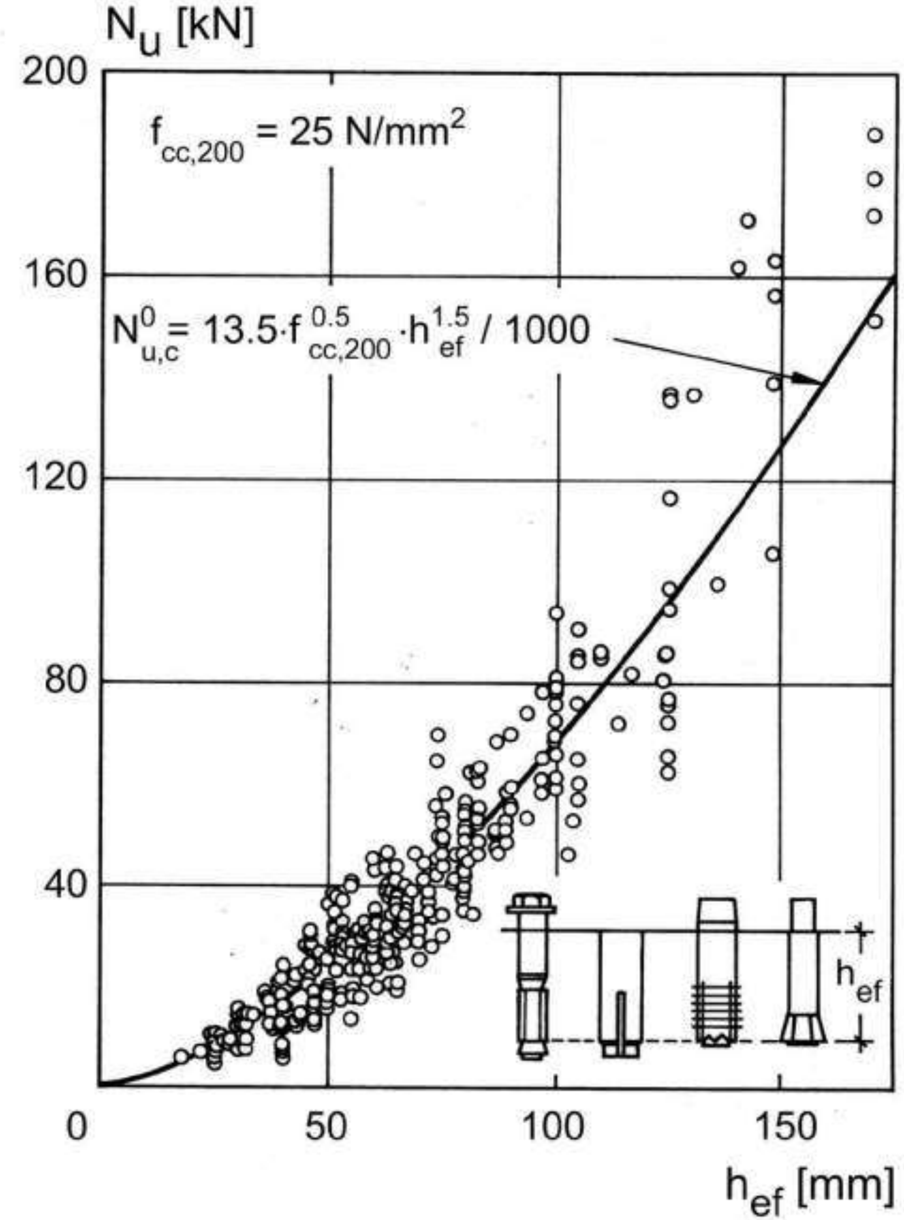
The diameter of the break-out body on the member surface is approx. 3 x anchorage depth h_{ef}.

$$N^0_{Rk,c} = 7{,}2 * \sqrt{f_{ck,cube}} * h_{ef}^{1,5}$$

Characteristic ressistance for expansion anchors for cracked concrete. (for non cracked concrete multiply by 1,4)

fischer

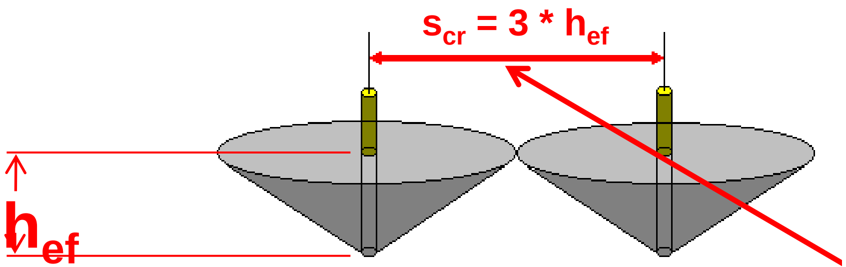
BEFESTIGUNGSSYSTEME



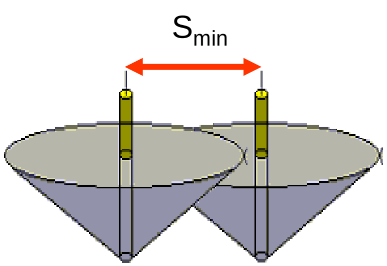
The concrete cone failure loads can be predicted with sufficient accuracy by the CC-Method.

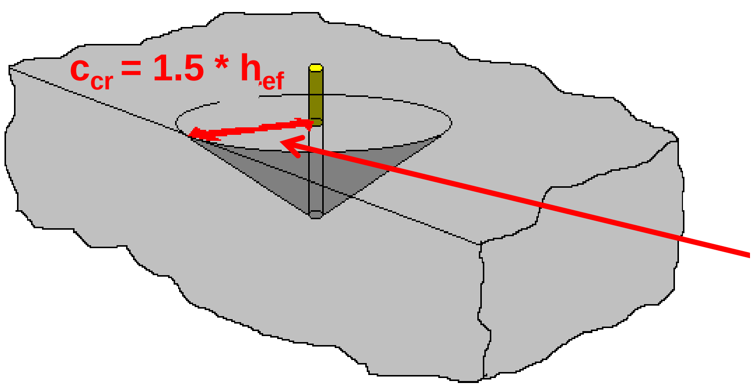
Characteristic spacing and edge distance

The maximum concrete break-out load can only be reached if this cone is allowed to build up unhindered.



The characteristic spacing of the anchor is 3 * h_{ef} .





The characteristic edge distance of the anchor is 1.5 * h_{ef} .

- **Base material (building material)**

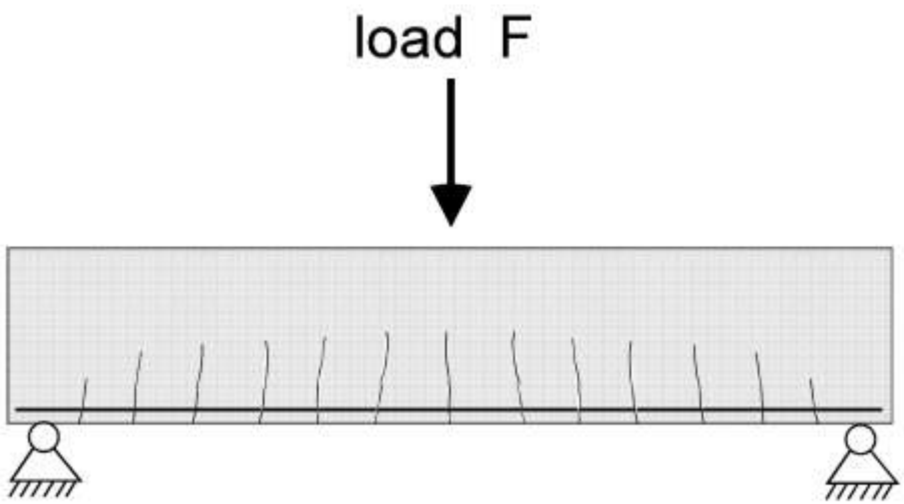
e.g. concrete

- **cracked concrete**

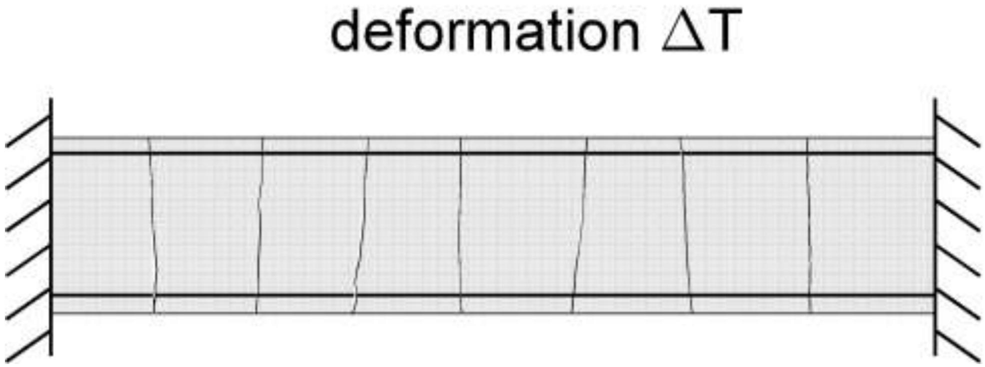
or

- **non cracked concrete**
- **concrete strength**

What is cracked concrete?



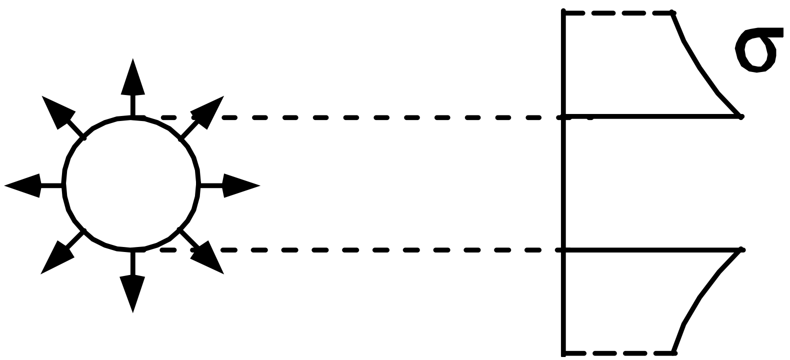
Cracking by loads



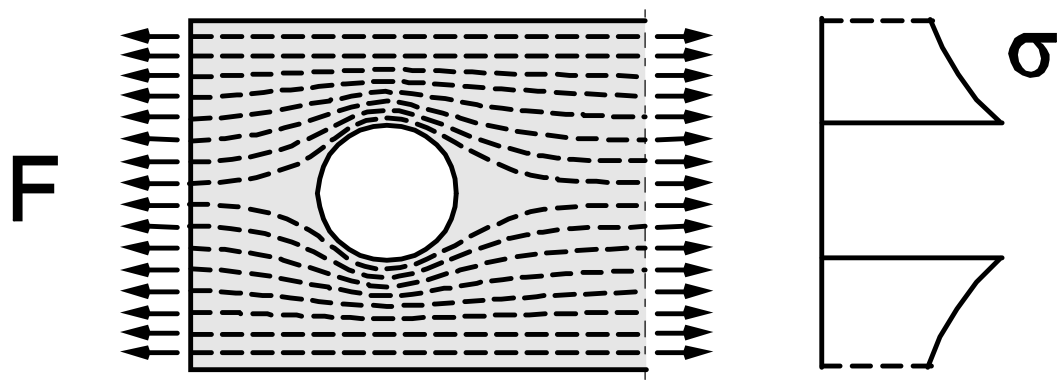
Cracking by induced deformations

There is a high probability that fasteners installed in non-cracked concrete will be located in a crack when cracks form.

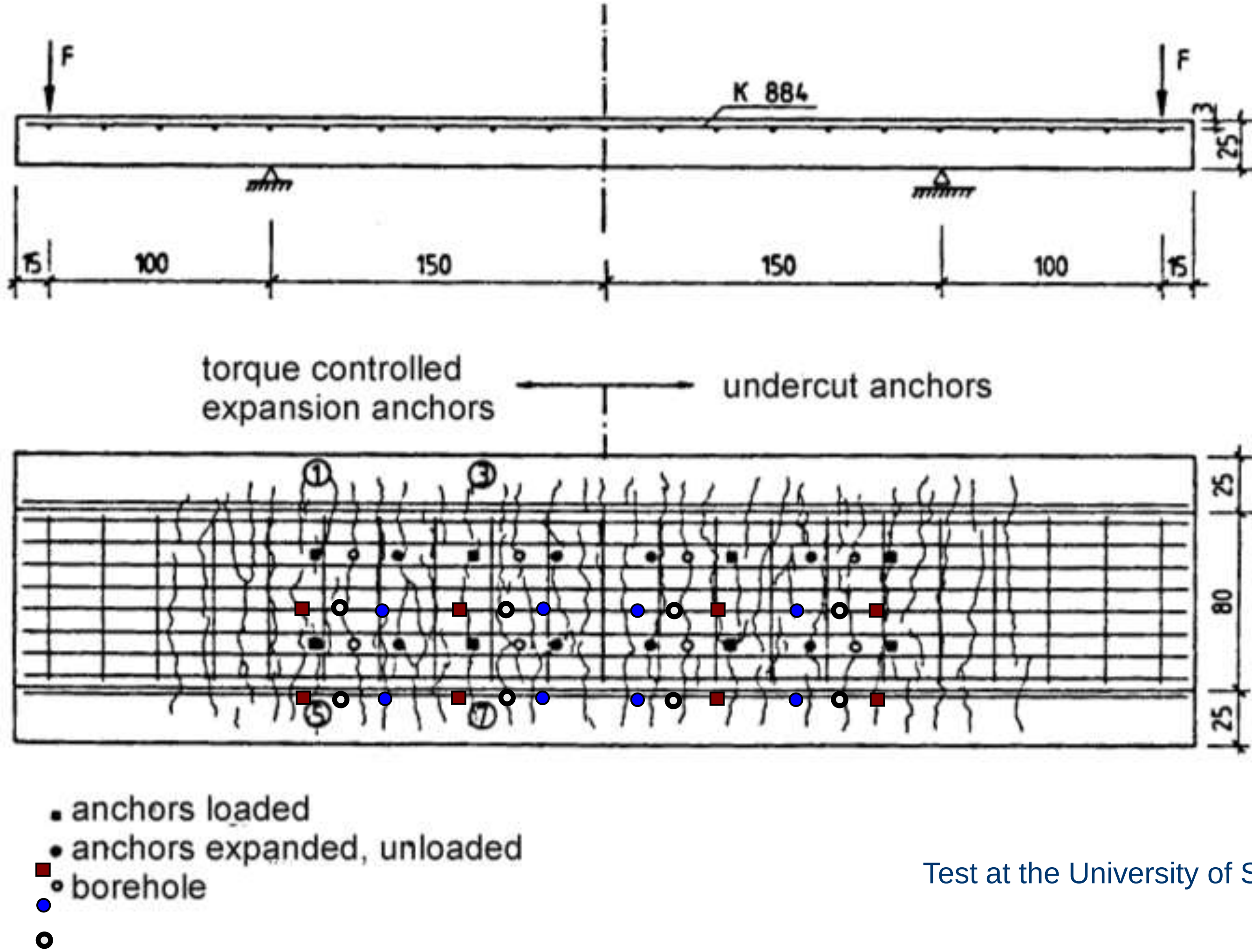
High tensile stresses are caused due to prestressing and loading.



Drill holes act as notches.

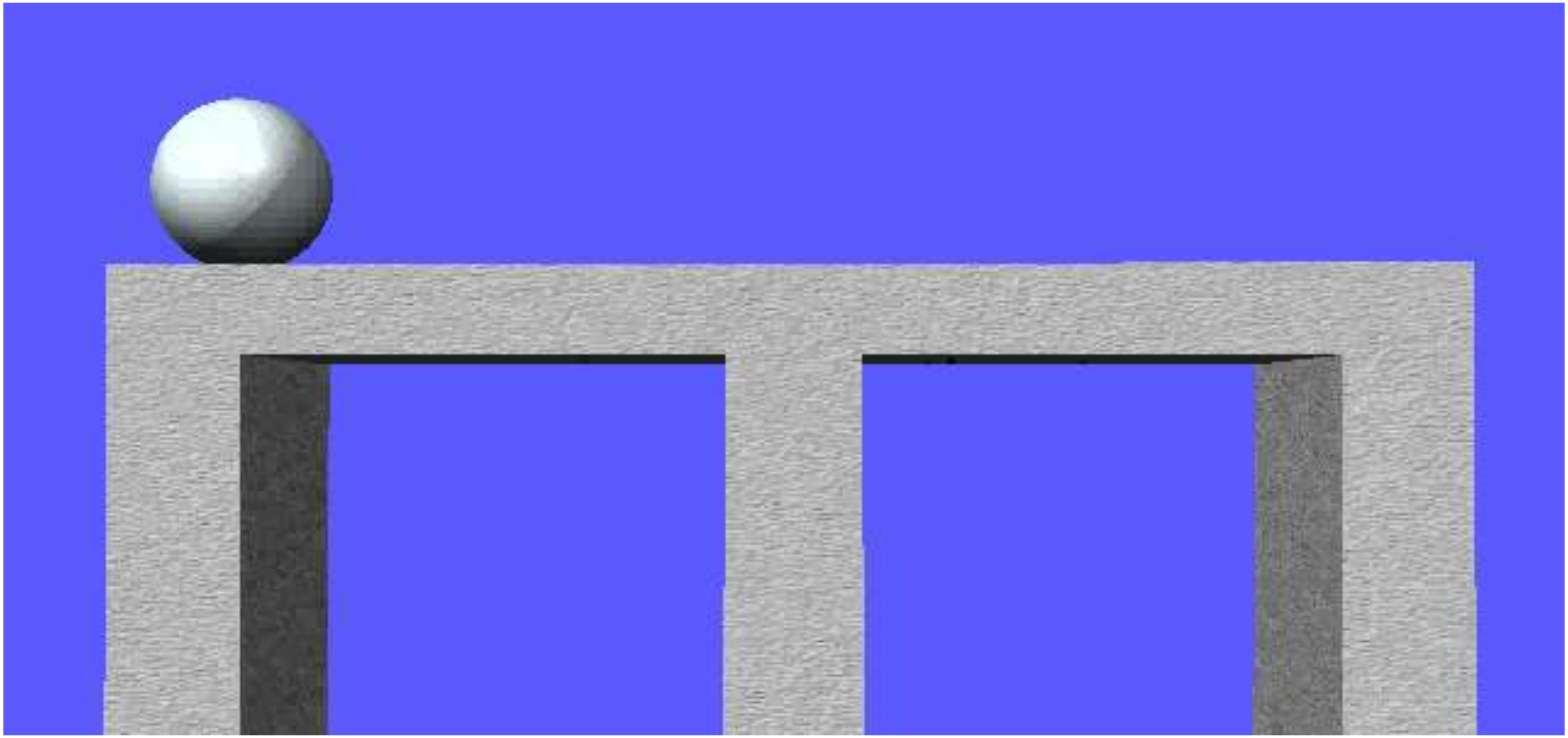


$$\sigma_m = F/A_b$$



Test at the University of Stuttgart

Anchors installed in uncracked concrete: Location to cracks



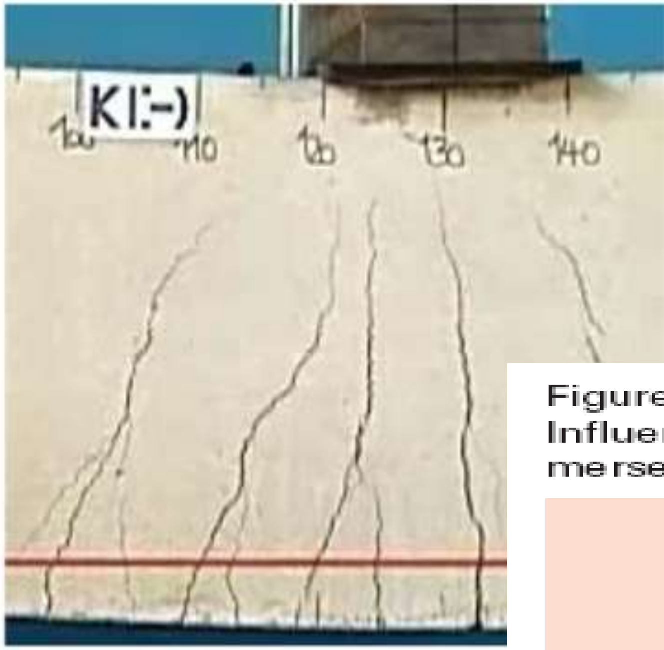
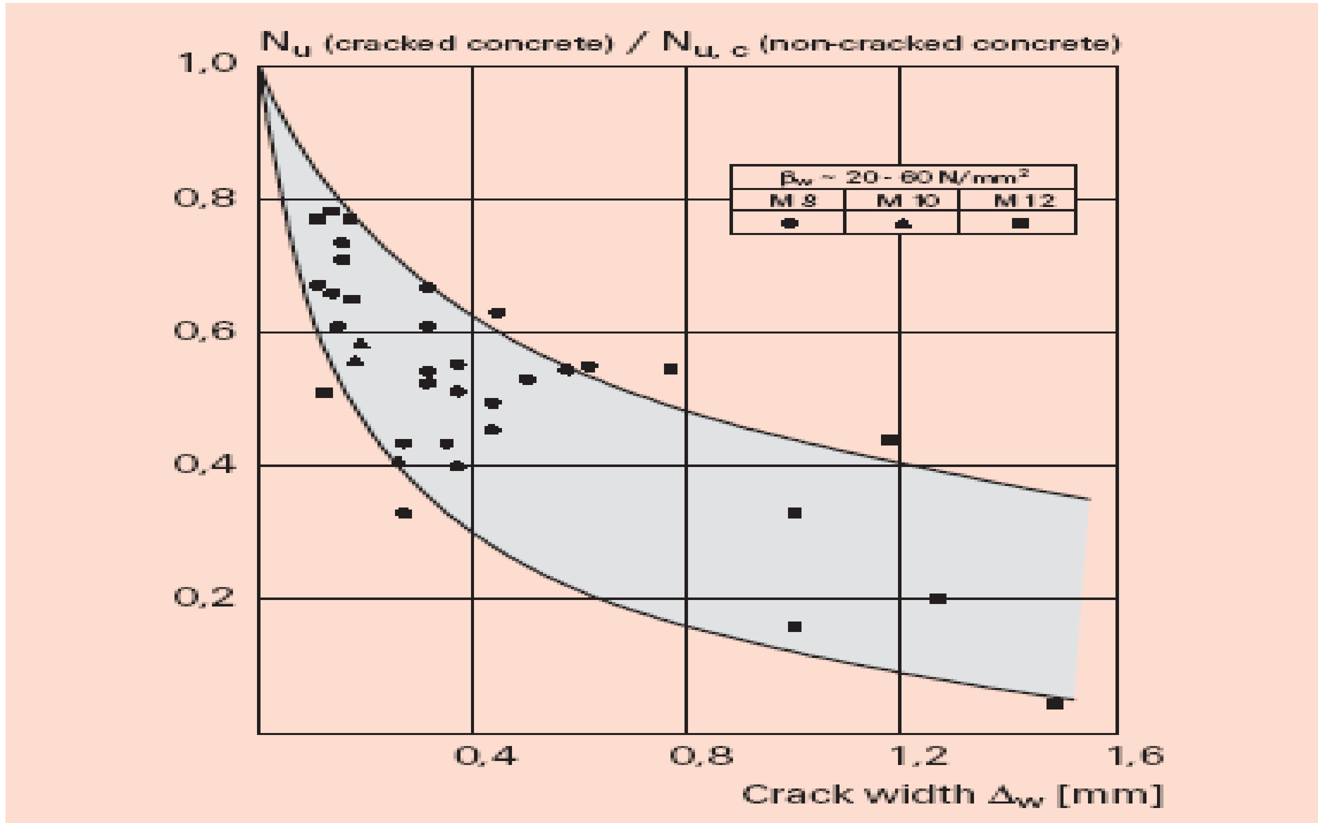


Figure 2.27:
Influence of cracks on the ultimate load of fully expanded hammerset anchors under axial tension load /5/



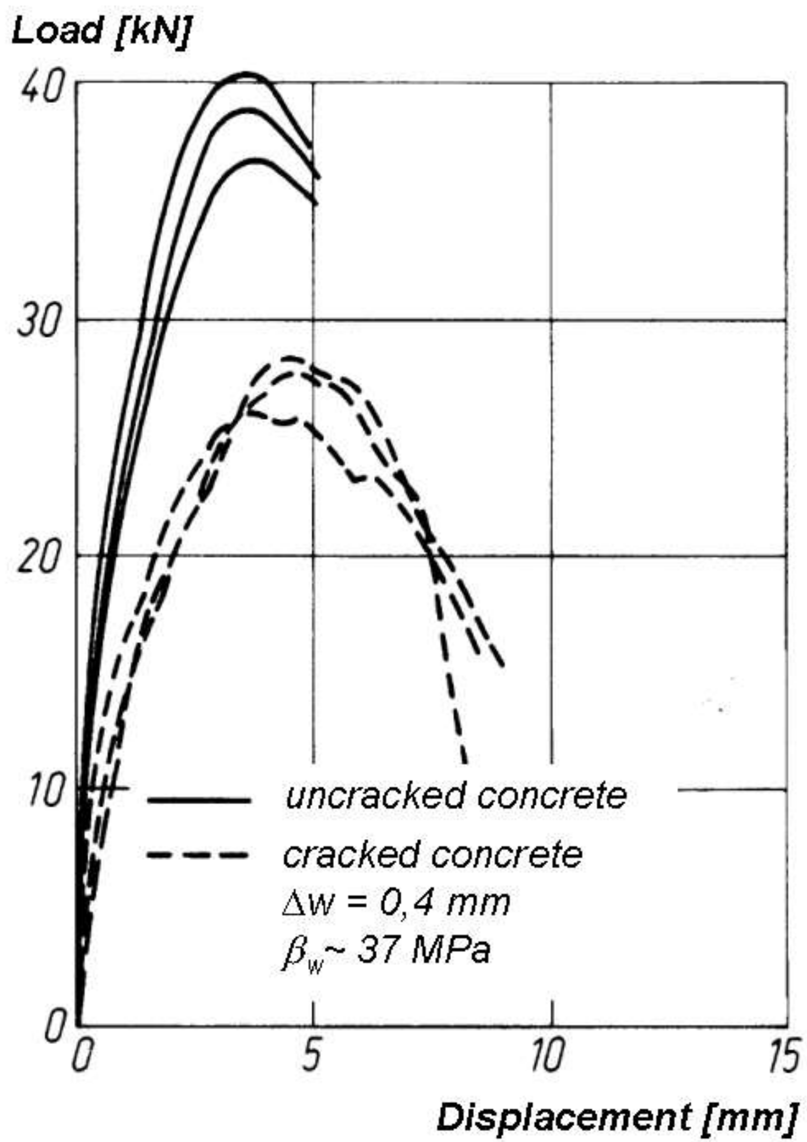
TORQUE-CONTROLLED ANCHORS

Designed for use in cracked concrete

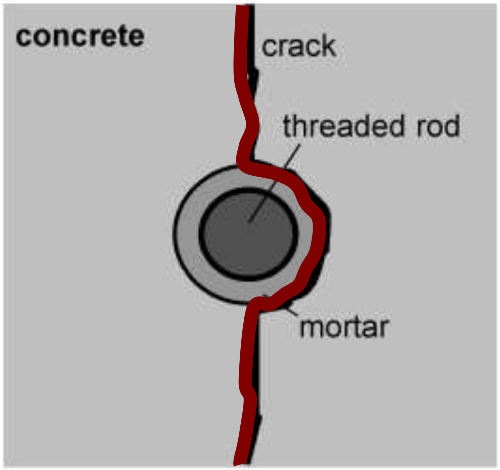
Reduction of failure load in cracked concrete

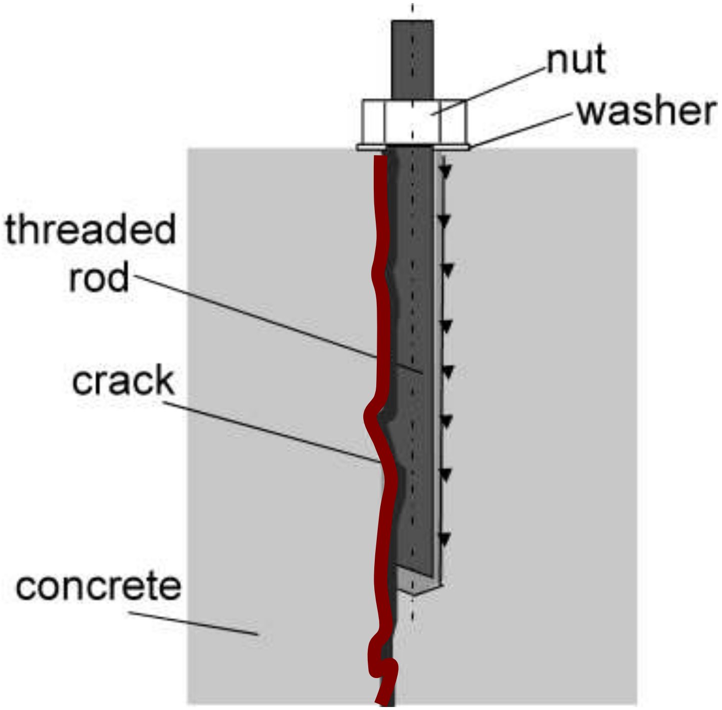
⇩

About 30 % reduction compared to non-cracked concrete



BONDED ANCHORS





CRACK

⇩

Destroys bond between mortar and concrete

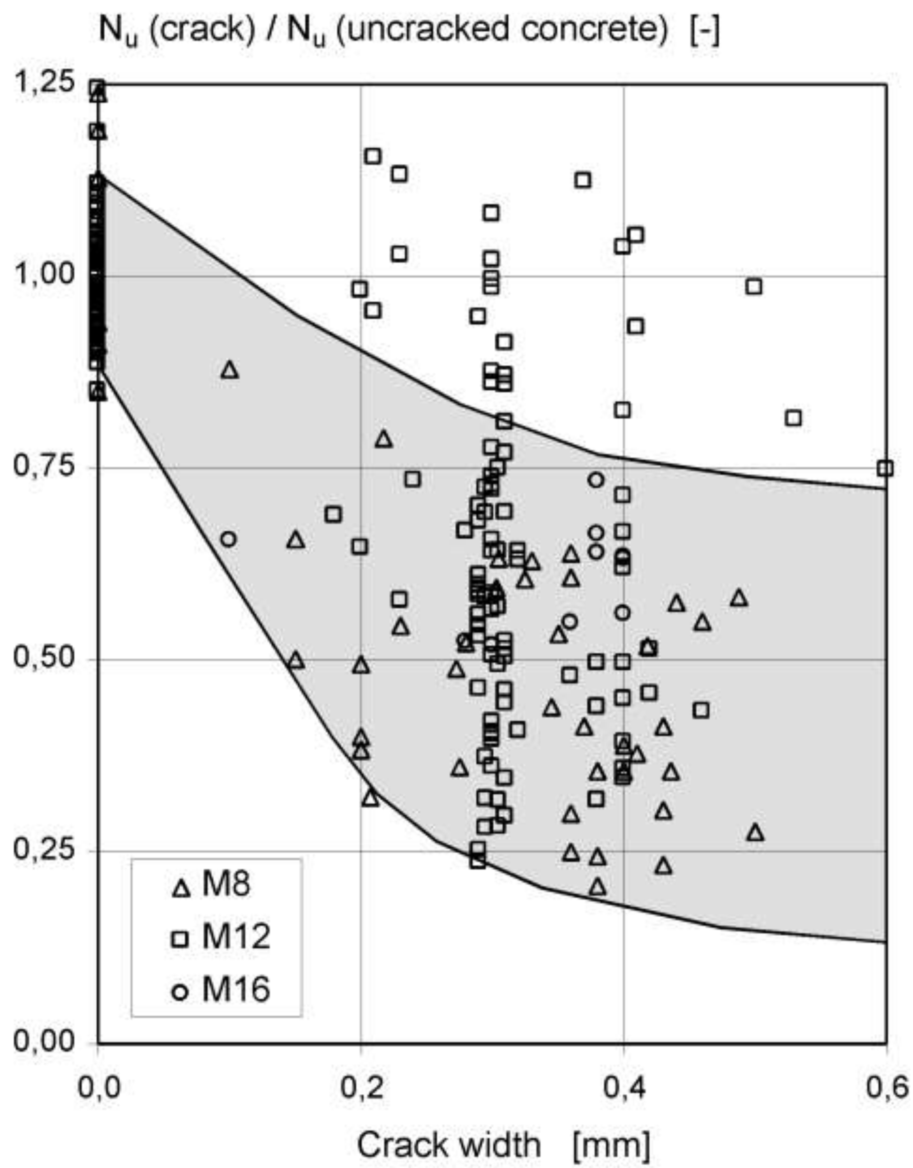
BONDED ANCHORS

Designed for use in non-cracked concrete

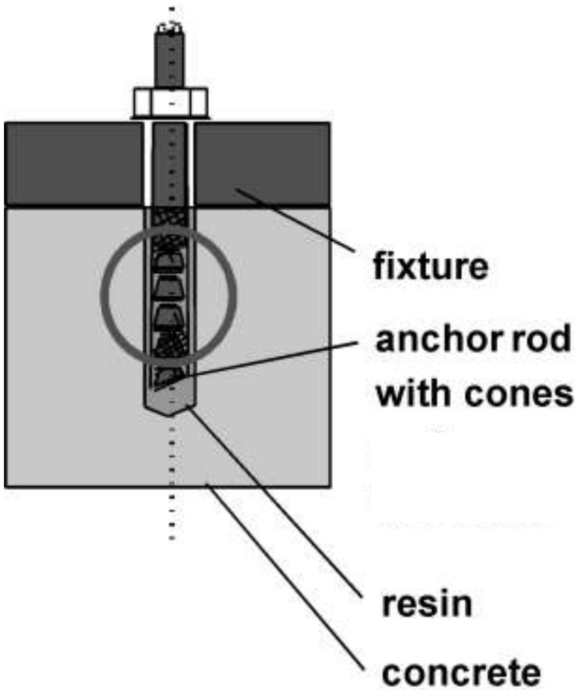
Reduction of failure load in cracked concrete

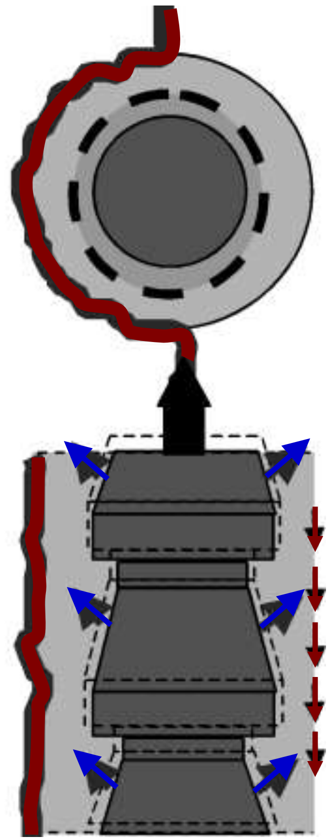
About 50 % reduction compared to non-cracked concrete

Large scatter



BONDED EXPANSION ANCHORS





CRACK

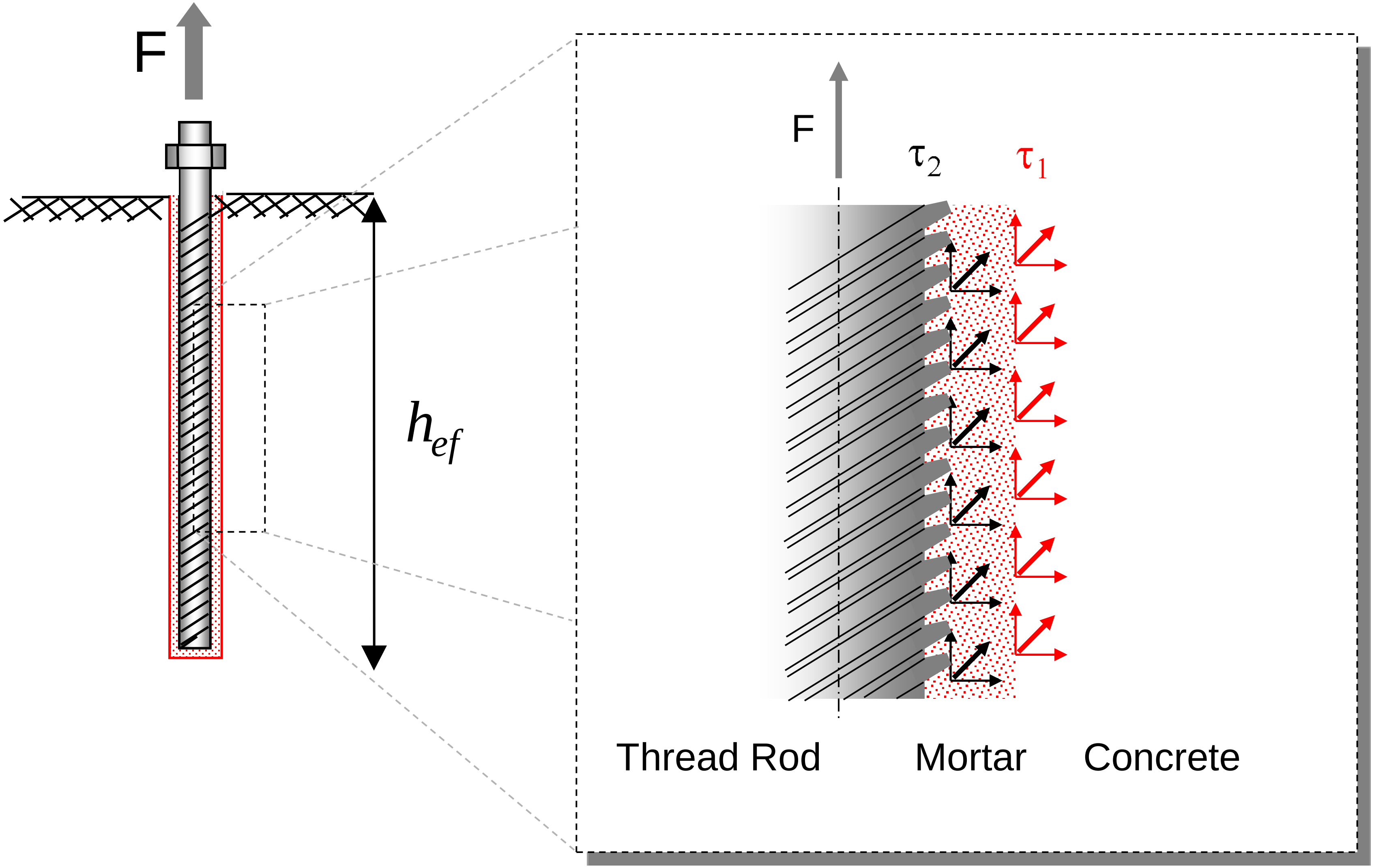
EXPANSION FORCES are generated by pulling the cones into the mortar.

BONDED EXPANSION ANCHORS

Most popular.

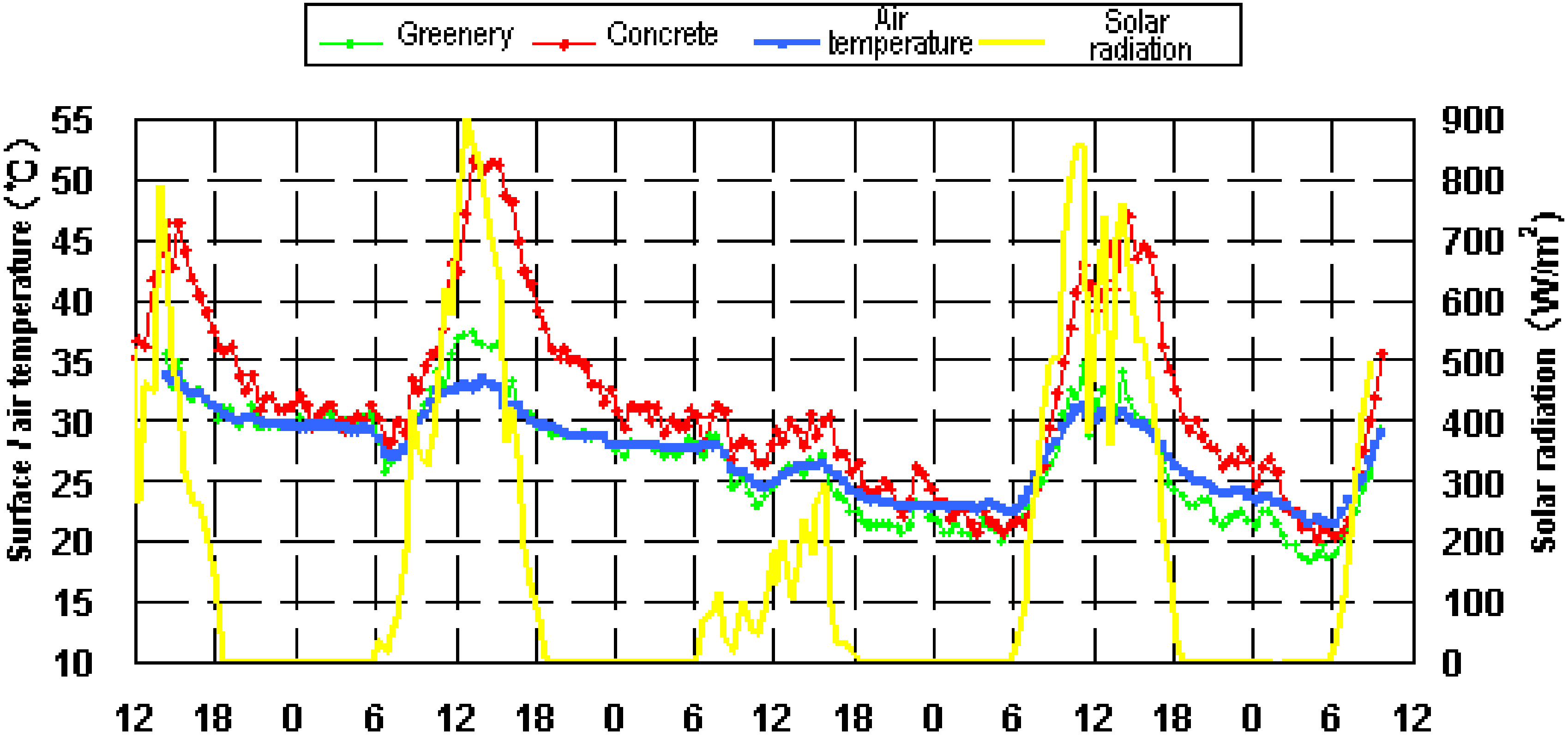
Non-cracked	cracked
FBNII 	FAZ II 
FH II 	FH II 
FEB 	FHB II 
FIS V 	FIS HB 

Load - transfer Mechanism of Bonded Anchors



Bonded Anchors

- Service temperature ranges and sustained loads



Fischer FIS EM

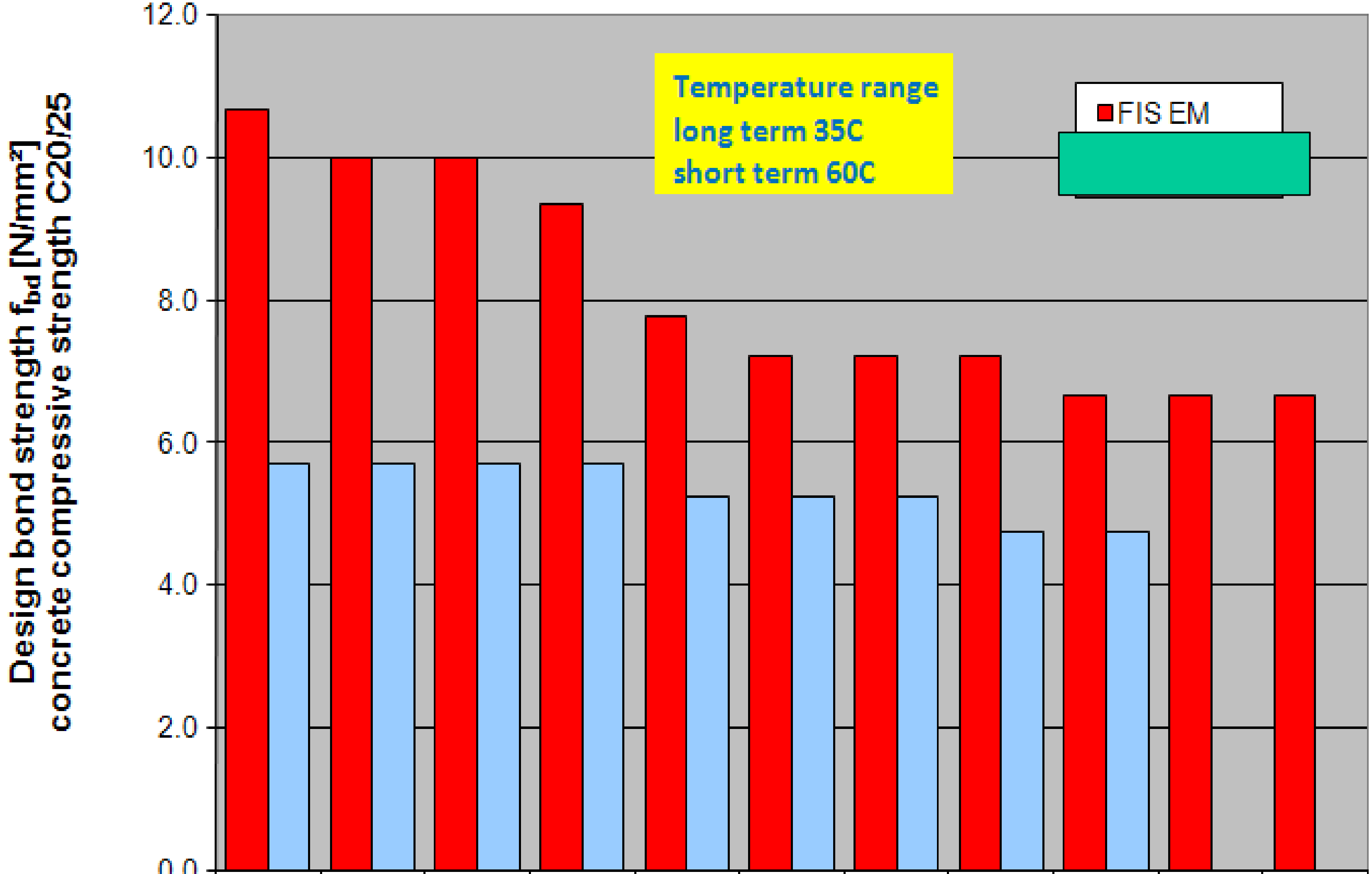
Table 15: Characteristic values to tension load reinforcing bars

Size	Ø d	8	10	12	14	16	18	20	22	24	25	26	28	30	32	36	40
Steel failure																	
Characteristic resistance reinforcing bars[5]	$N_{Rk,s}$ [kN]	28	44	63	85	111	140	173	209	249	270	292	339	389	443	560	691
Partial safety factor	$\gamma_{Ms,N}$[1] [-]	1,4															
Combined pullout and concrete cone failure																	
Diameter for calculation	d [mm]	8	10	12	14	16	18	20	22	24	25	26	28	30	32	36	40
Characteristic bond resistance in non-cracked concrete C20/25																	
Temperature range I[4] (60°C / 35°C)	$\tau_{Rk,ucr}$ [N/mm²]	16	15	15	14	14	14	13	13	13	13	13	13	12	12	12	12
Temperature range II[4] (72°C / 50°C)	$\tau_{Rk,ucr}$ [N/mm²]	13	12	12	12	11	11	11	11	11	10	10	10	10	10	9,5	9,5
Characteristic bond resistance in cracked concrete C20/25																	
Temperature range I[4] (60C / 35°C)	$\tau_{Rk,cr}$ [N/mm²]	7	7	7	7	7	7	7	7	7	7	7	7	7	5	5	5
Temperature range II[4] (72°C / 50°C)	$\tau_{Rk,cr}$ [N/mm²]	6	6	6	6	6	6	6	6	6	6	6	6	6	4	4	4

Competitor

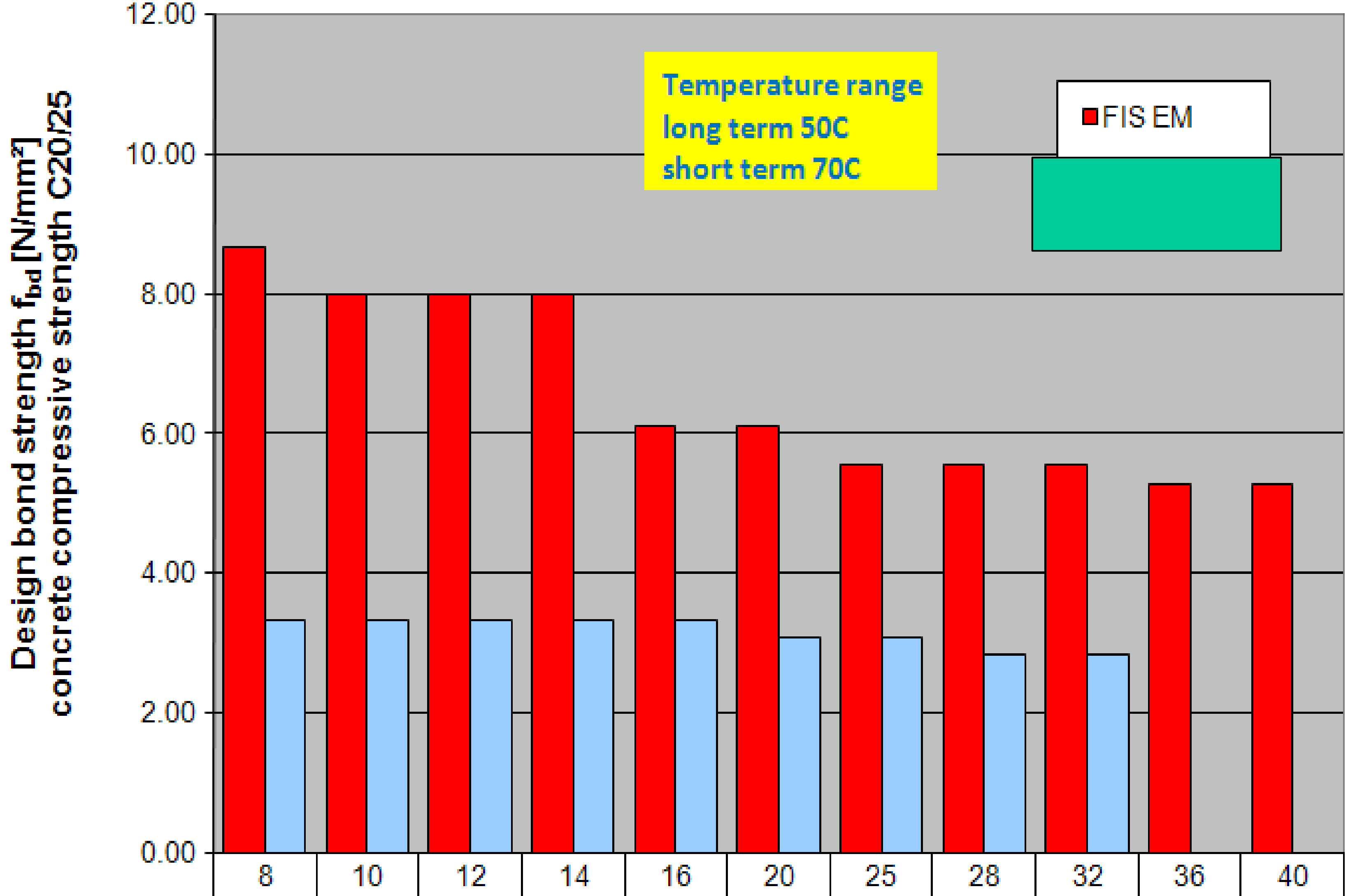
Table 13: Design method A, Characteristic tension load values

			Ø8	Ø10	Ø12	Ø14	Ø16	Ø20	Ø25	Ø26	Ø28	Ø30	Ø32
Steel failure rebar													
Characteristic tension resistance for rebar BSt 500 S acc. to DIN 488 [1]	$N_{Rk,s}$	[kN]	**28**	**43**	**62**	**85**	**111**	**173**	**270**	**-**	**339**	**-**	**442**
Partial safety factor for rebar BSt 500 S acc. to DIN 488 [2]	$\gamma_{Ms,N}$[3]	[-]	1,4										
Combined Pull-out and Concrete cone failure [4]													
Diameter of rebar	d	[mm]	8	10	12	14	16	20	25	26	28	30	32
Characteristic bond resistance in non-cracked concrete C20/25													
Temperature range I[5]: 40°C/24°C	$\tau_{Rk,ucr}$	[N/mm²]	**15**	**15**	**15**	**14**	**14**	**14**	**13**	**13**	**13**	**13**	**13**
Temperature range II[5]: 58°C/35°C	$\tau_{Rk,ucr}$	[N/mm²]	**12**	**12**	**12**	**12**	**11**	**11**	**11**	**11**	**10**	**10**	**10**
Temperature range III[5]: 70°C/43°C	$\tau_{Rk,ucr}$	[N/mm²]	**7**	**7**	**7**	**7**	**7**	**6,5**	**6,5**	**6,5**	**6**	**6**	**6**



	8	10	12	14	16	20	25	28	32	36	40
FIS EM	10.7	10.0	10.0	9.3	7.8	7.2	7.2	7.2	6.7	6.7	6.7
	5.7	5.7	5.7	5.7	5.2	5.2	5.2	4.8	4.8		

rebar diameter



	8	10	12	14	16	20	25	28	32	36	40
FIS EM	8.67	8.00	8.00	8.00	6.11	6.11	5.55	5.55	5.55	5.27	5.27
	3.3	3.3	3.3	3.3	3.3	3.1	3.1	2.9	2.9		

rebar diameter

Factors influencing the strength of bonded anchors

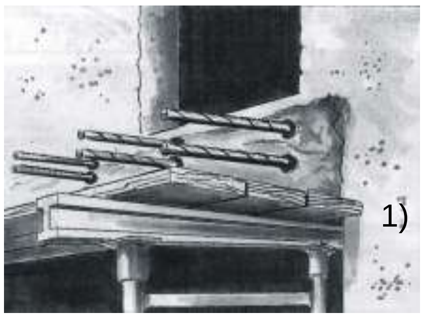
- Drilling method
- Hole cleaning
- Mixing
- Installation in wet concrete
- Submerged installation
- Hole orientation
- Temperature
- Freeze/thaw
- Chemicals (alkalinity)
- Sustained loading
- Fatigue, seismic
- Fire
- Cracked concrete

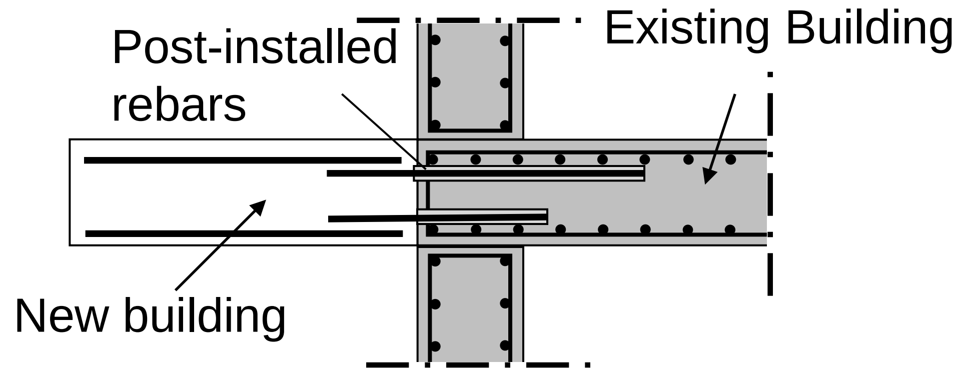
Influence is product dependent: Prequalification is necessary

Anchor design easy……… **COMPUFIX 8.4**

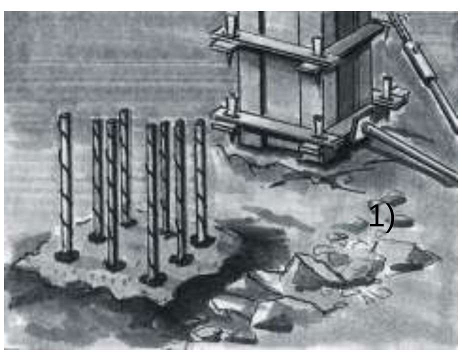
- free download
- ask for installation
- free training session

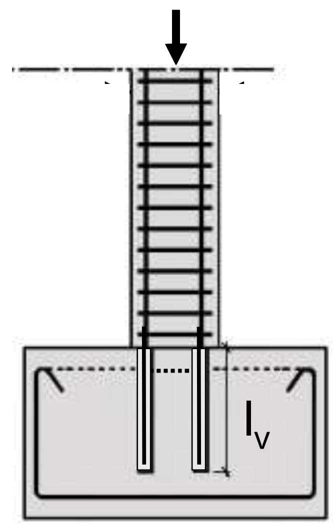
Connecting new and existing buildings using post-installed rebars



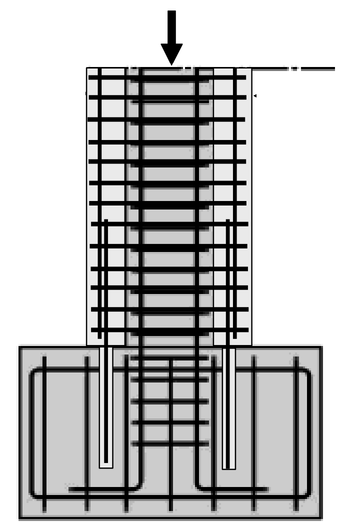


Strengthening with post-installed rebar connections





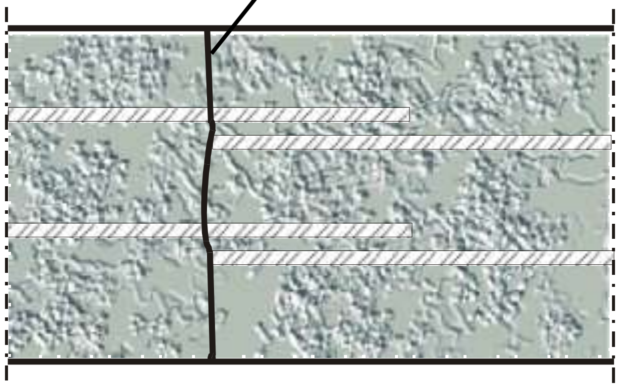
Adding new columns



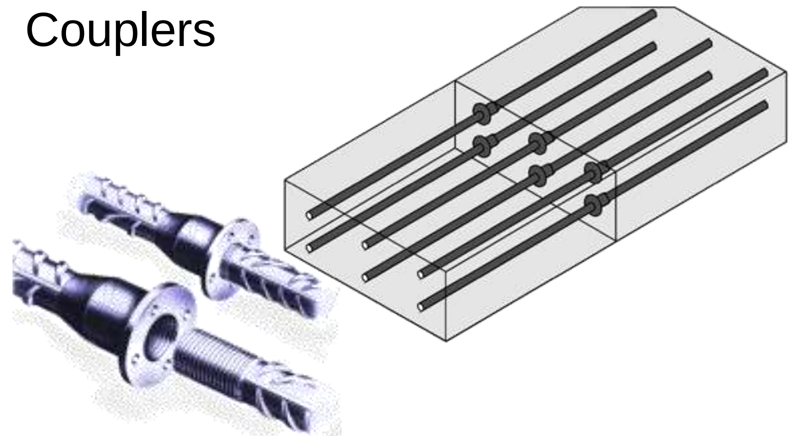
Strengthen columns

Source: 1) (Hilti)

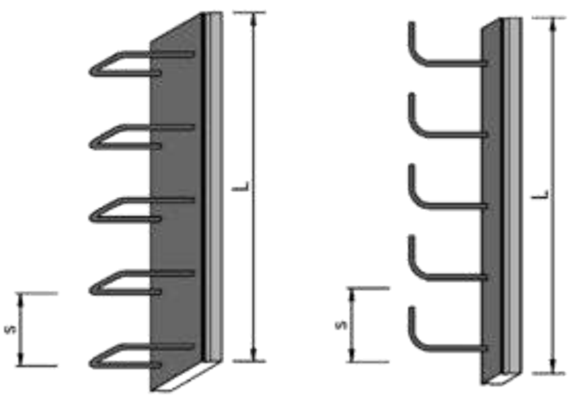
Formwork Joint



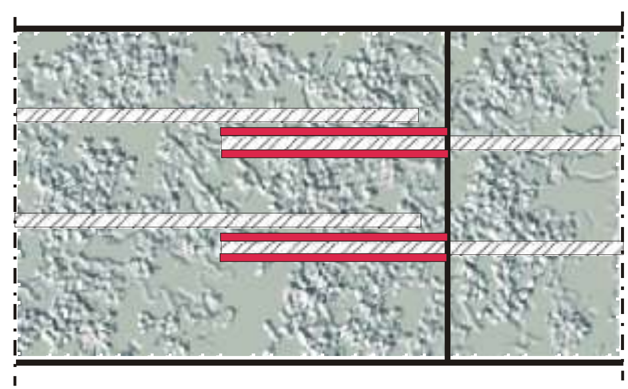
Couplers

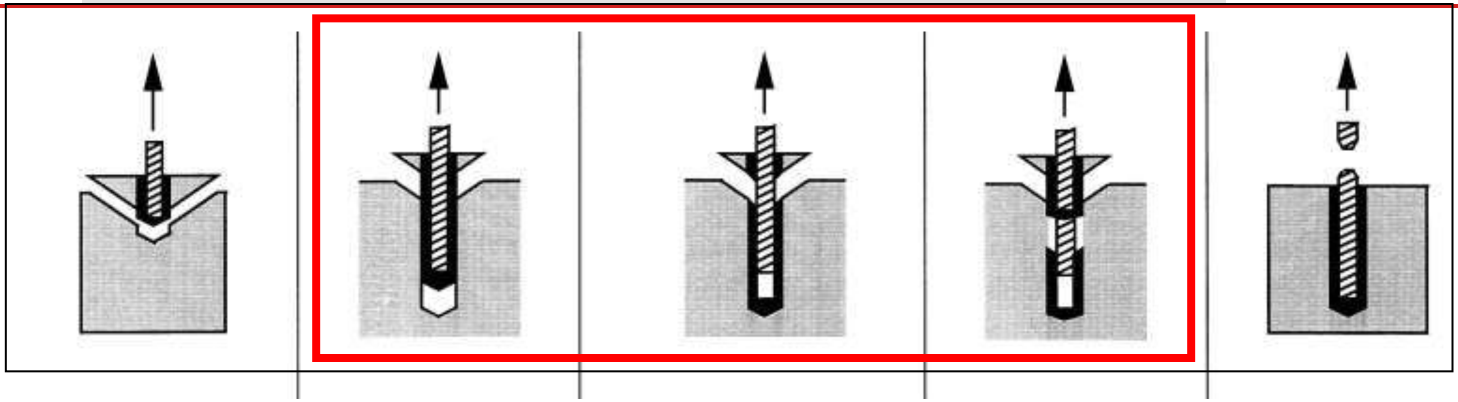


Flashing Boxes with Stirrups

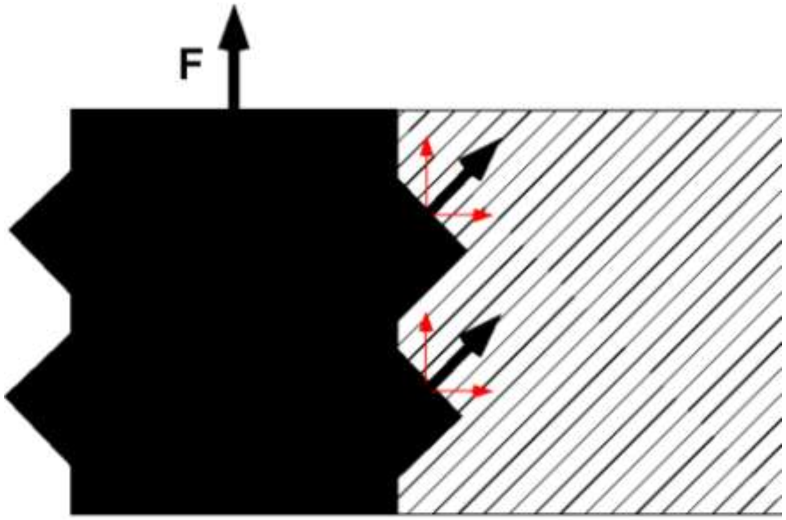


Post-Installed
Bonded Rebar Connection

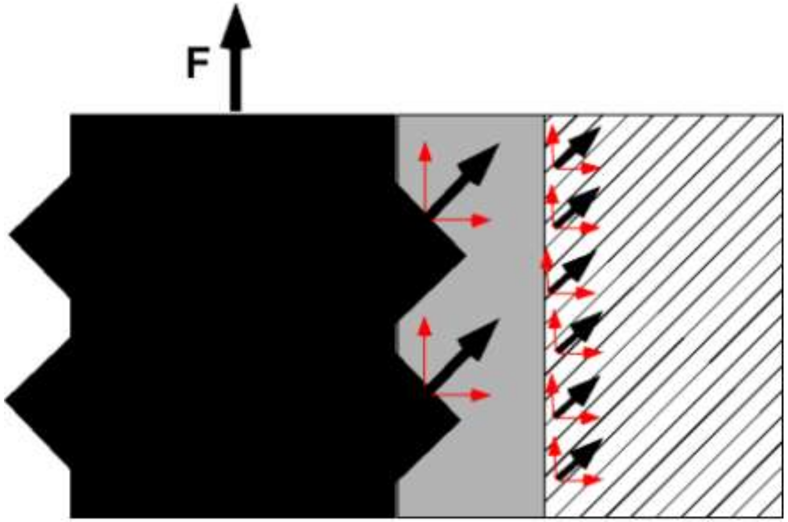




1)



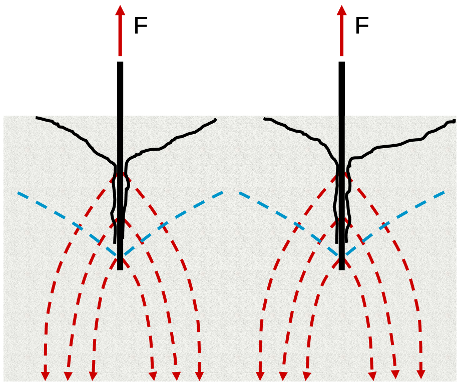
Cast-in-place



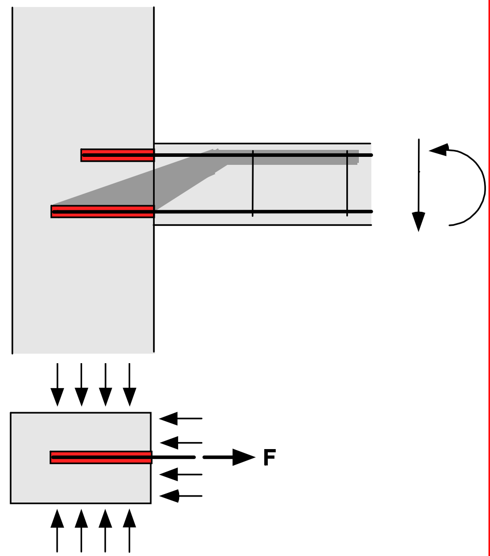
Post-installed

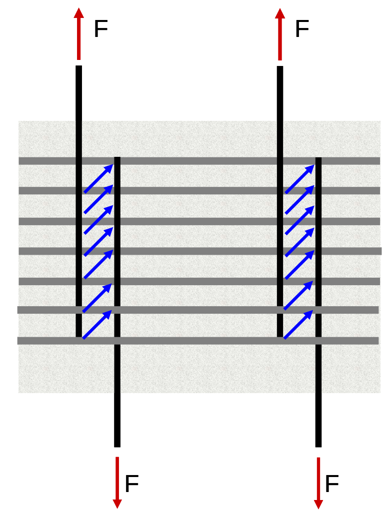
Source: 1) Kunz, Cook, Fuchs, Spieth (1998)

Fastening Technique



Reinforced Concrete

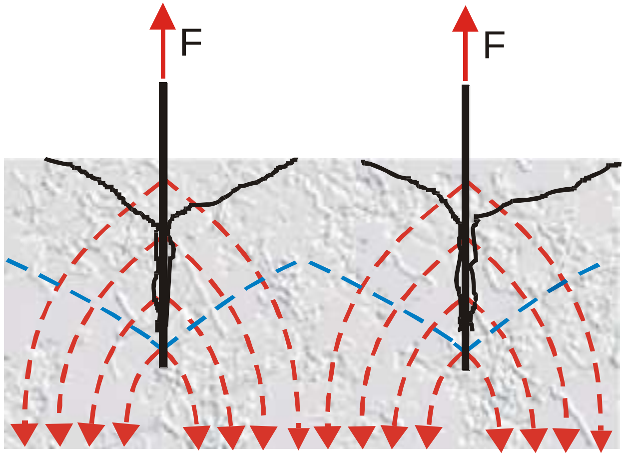




Without load transfer to existing reinforcement

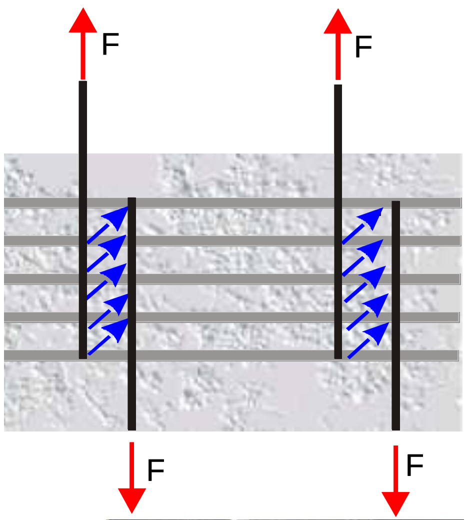
With load transfer to existing reinforcement

Load transfer



- **Anchor theory**
  - ➔ load transfer via tensile strength of concrete
  - ➔ consideration of edge distance and spacing
  - ➔ ***maximum*** anchorage length
    4 - 20 d_s (ETAG)
  - ➔ design
    - ETAG 001 Annex C / TR 029
  - ➔ Failure modes
    - pull-out
    - concrete cone
    - steel
    - splitting

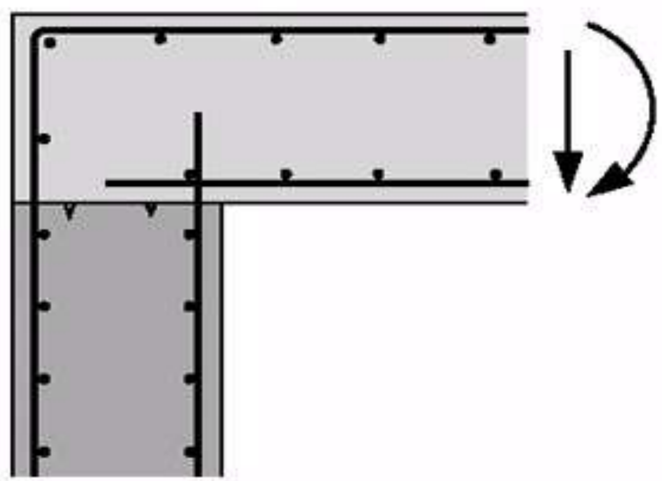
Load transfer

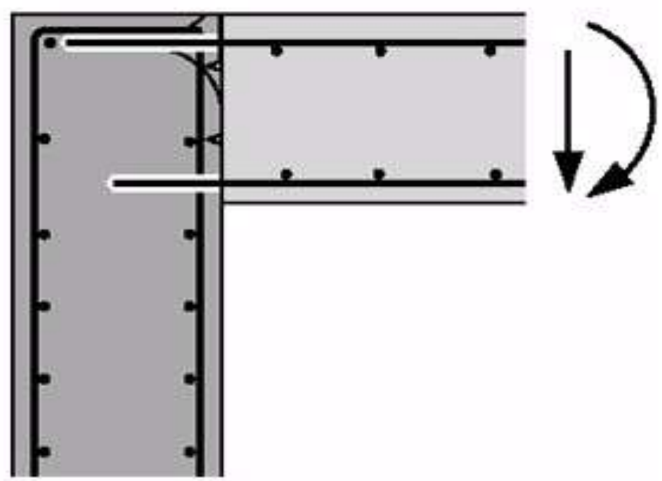


- **Rebar theory**
  - ➔ load transfer via **existing reinforcement**
  - ➔ consideration of existing reinforcement
  - ➔ minimum concrete cover (2 cm - 5 cm)
  - ➔ consideration of development length and lap splic
  - ➔ ***minimum*** development length: 10 - 15 d_s
  - ➔ ***maximum*** development length: up to 70 d_s
  - ➔ design acc. to structural concrete codes
    - – Eurocode 2
    - – DIN 1045-1
    - – ACI 318
    - – BS 8110 (1 April 2010 EC2 is taking over)
  - ➔ failure modes
    - – steel
    - – splitting?

cast-in

post-installed

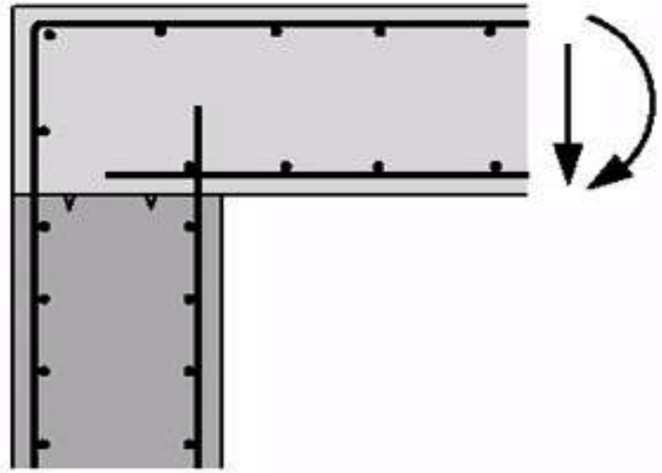




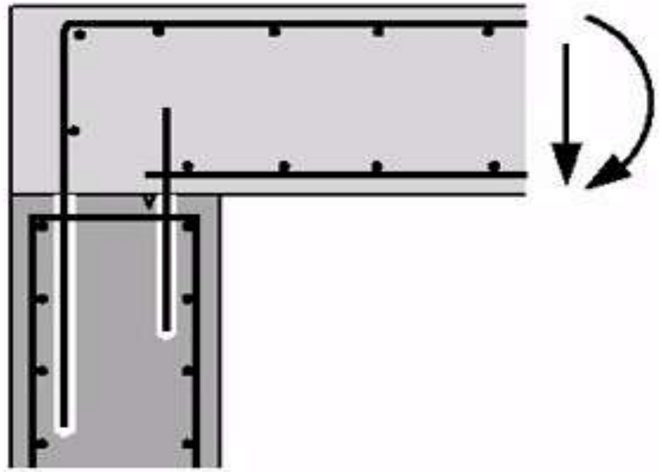
- lap splice with existing reinforcement
- lap length must be sufficient

→ ***permissible application***

cast-in

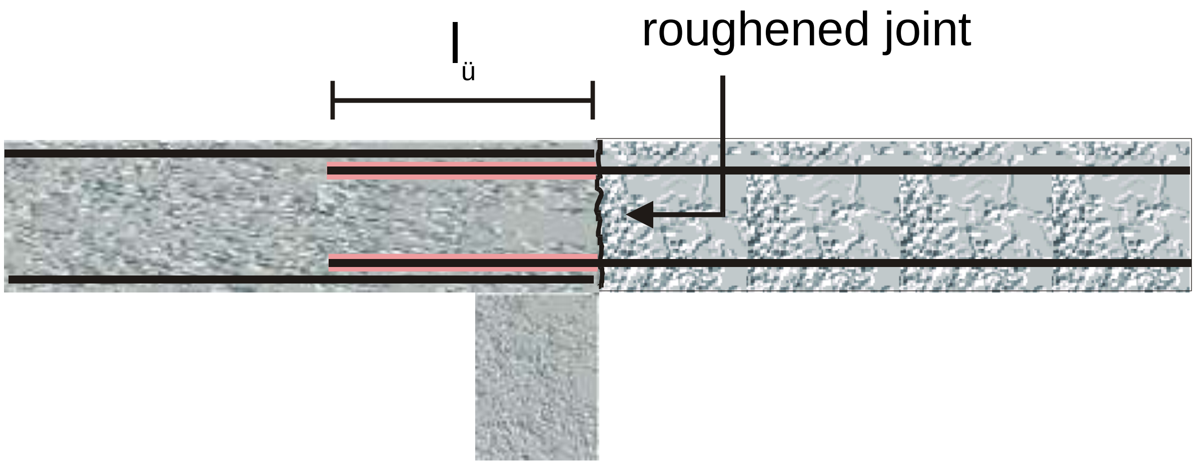


post-installed



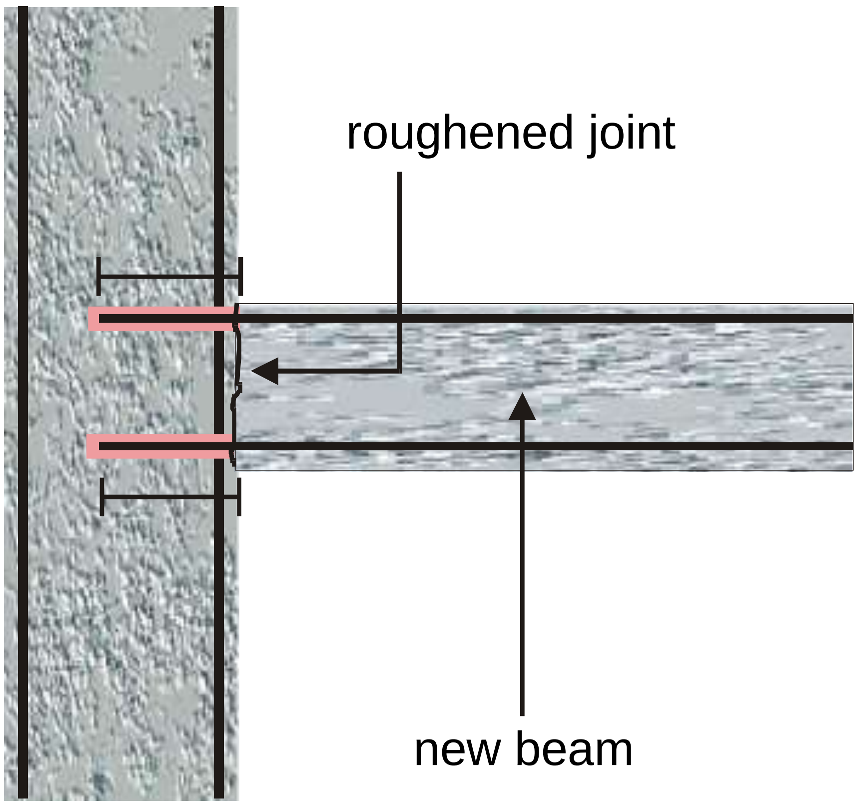
- lap splice with existing reinforcement
- lap length must be sufficient

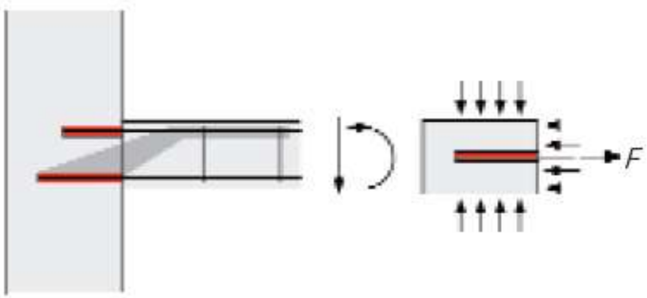
➔ ***permissible application***



- existing structure with reinforcement
- ***without*** transverse reinforcement allowed for rebars with $d_s \leq 14$ mm
- ***with*** transverse reinforcement allowed for all rebar diameters

➔ ***permissible application***

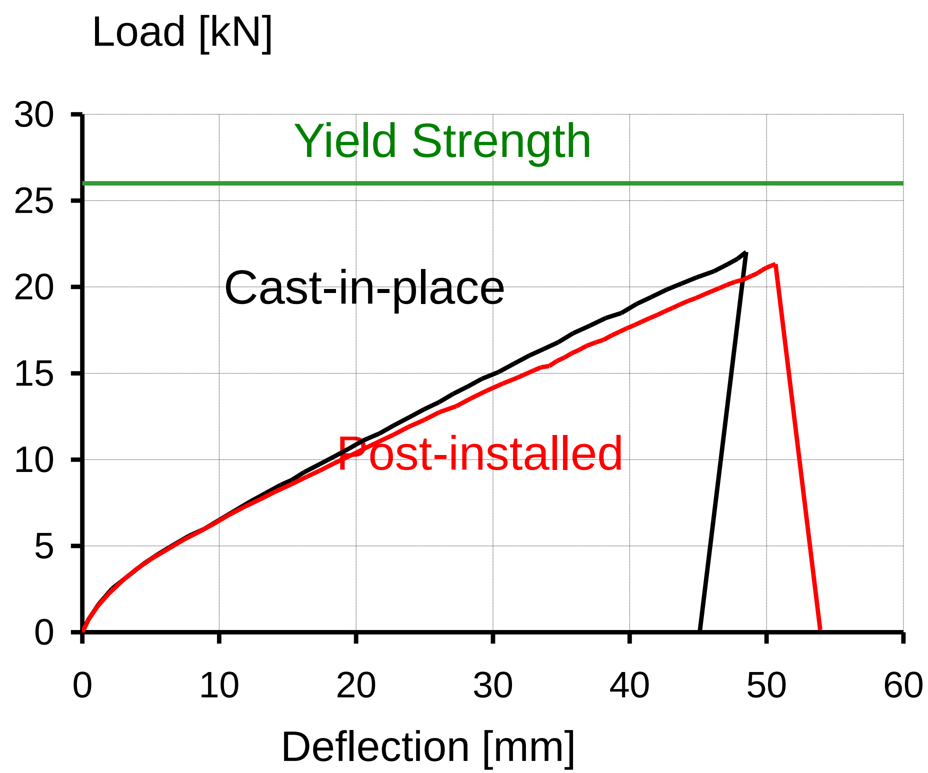




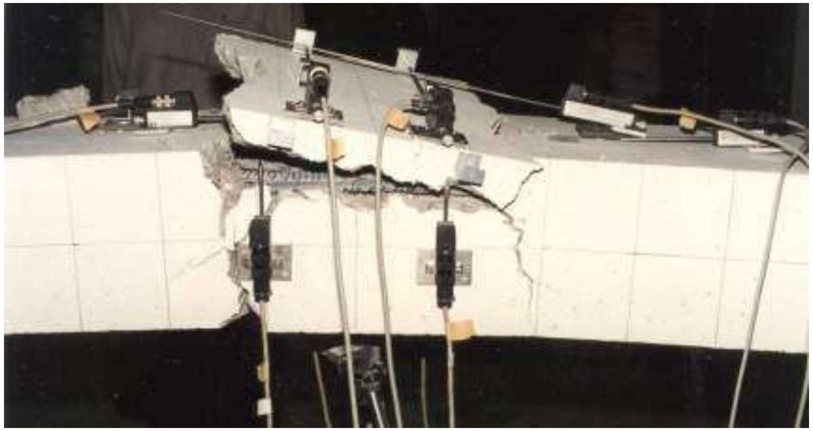
Design as simple beam

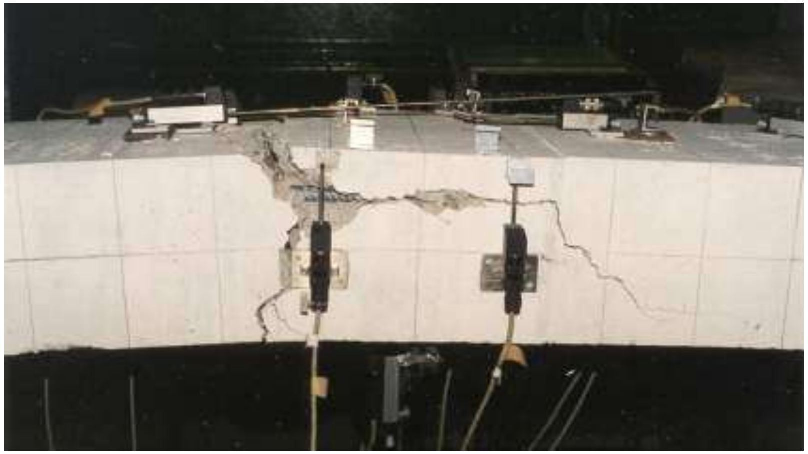
- development length of bottom reinforcement ≥ 10 d_s
- concrete compression struts prevent concrete cone failure of the bottom reinforcement
- constructional anchoring of the top reinforcement

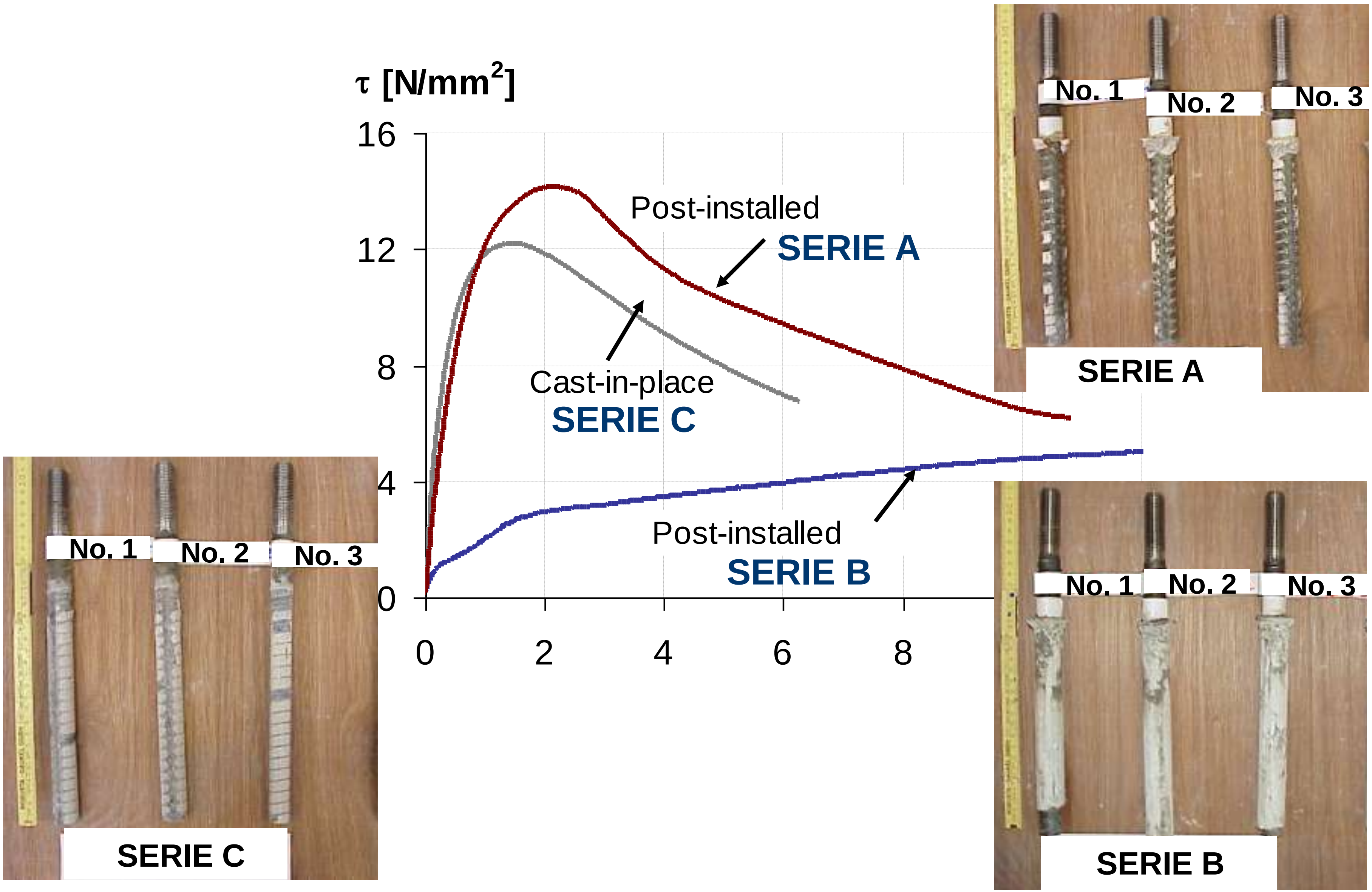
➔ ***permissible application***

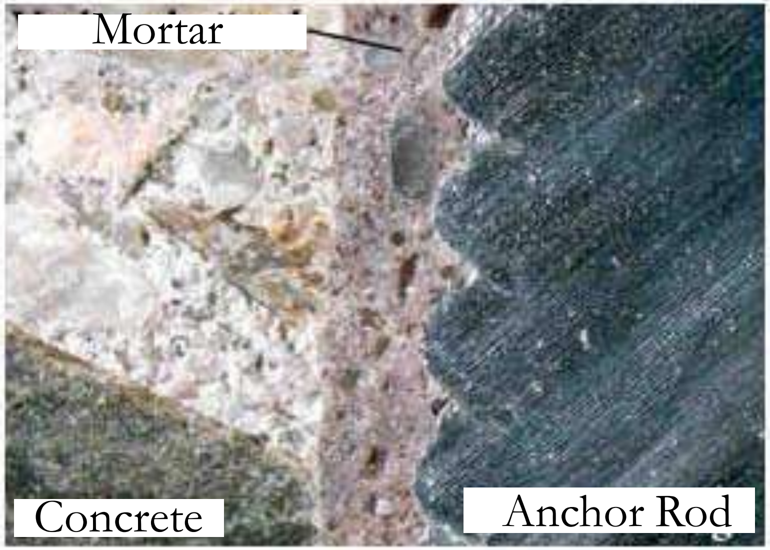


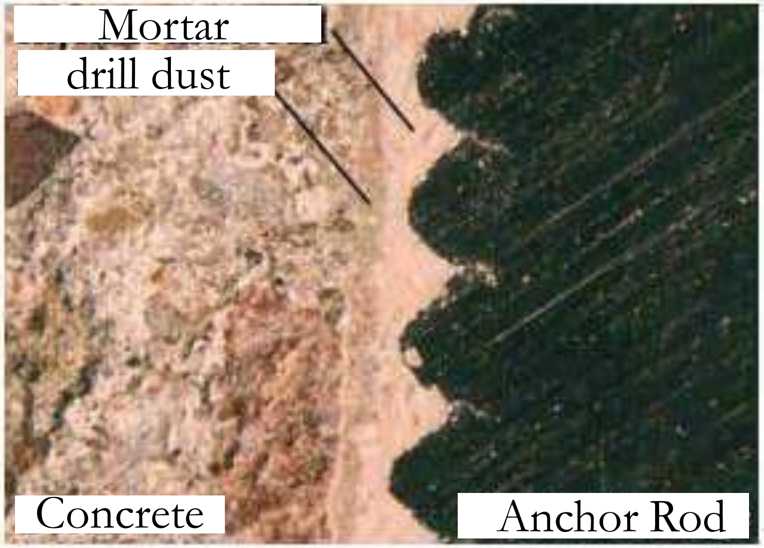
Load [kN]
30
25
20
15
10
5
0
Yield Strength
Cast-in-place
Post-installed
0
10
20
30
40
50
60
Deflection [mm]

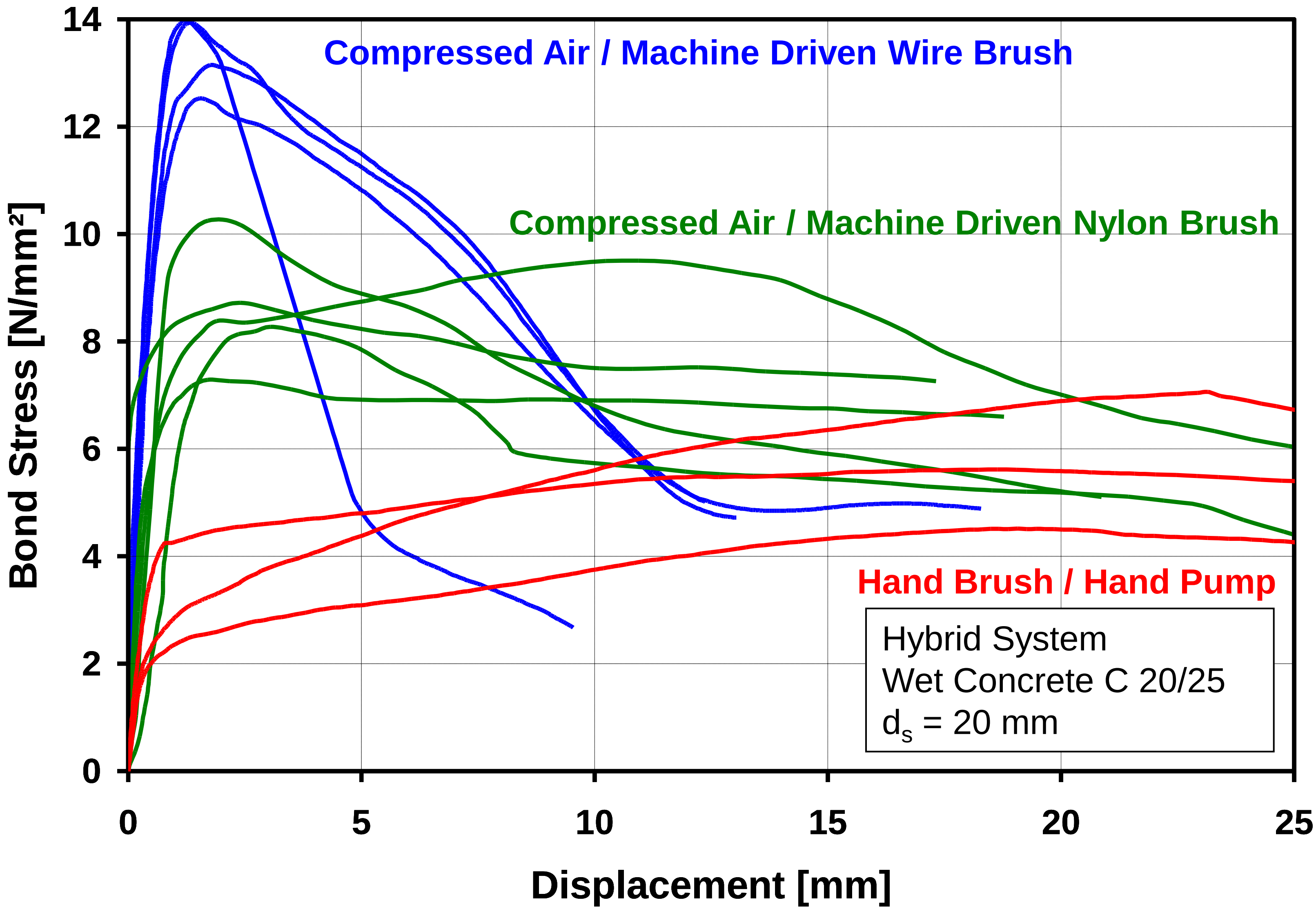





τ [N/mm²]
16
12
8
4
0
0
2
4
6
8
Post-installed
SERIE A
Cast-in-place
SERIE C
Post-installed
SERIE B
No. 1
No. 2
No. 3
SERIE A
No. 1
No. 2
No. 3
SERIE B
No. 1
No. 2
No. 3
SERIE C

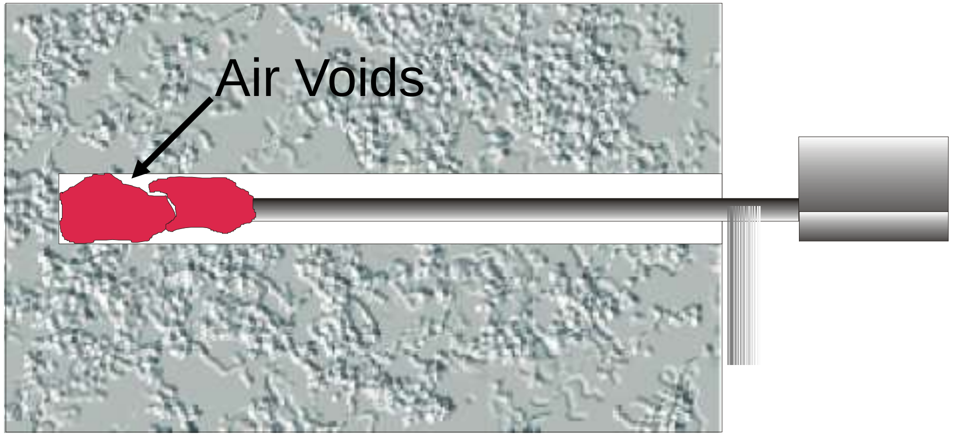

Mortar
Concrete
Anchor Rod


Mortar
drill dust
Concrete
Anchor Rod

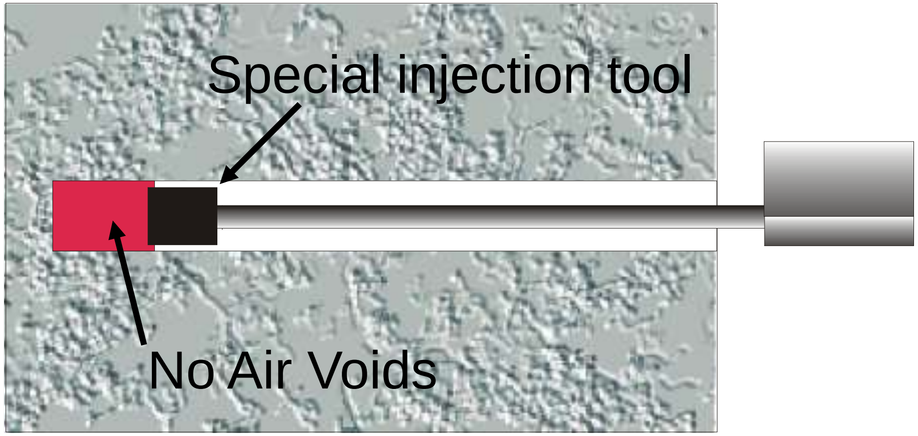


Compressed Air / Machine Driven Wire Brush
Compressed Air / Machine Driven Nylon Brush
Hand Brush / Hand Pump
Hybrid System
Wet Concrete C 20/25
d$_s$ = 20 mm
Bond Stress [N/mm²]
Displacement [mm]
0
2
4
6
8
10
12
14
0
5
10
15
20
25

Standard injection tool



Newly developed injection tool



Use of special injection tool which is optimized to the drilling diameter

Rebar design easy……….. **Rebarfix**

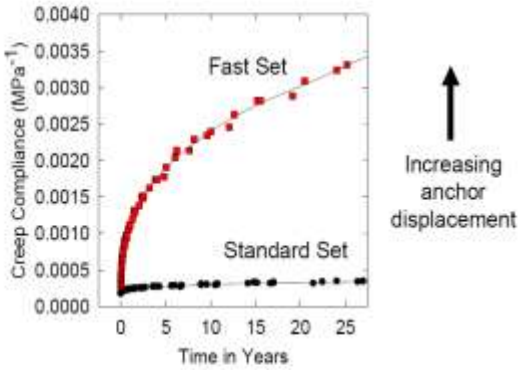
- free download
- ask for installation
- free training session

SUMMARY

- Modern **fastening technique** is **increasingly used** in the building industry.
- **New** and **innovative fastening systems** have been developed.
- **Reliable design methods** have been incorporated in design guides.
- However, fastenings are currently often **not used** in practice **with the same confidence** as other connections (e.g. welding), mainly because the **training** of designers and especially installers is too poor.

⇨ **It is believed that by improving the training of designers and installers the field of application of modern fastening technique will be expanded.**

fischer FIXING SYSTEMS



- **Specification advice** to evaluate anchors' suitability
- **Installation Training** to eliminate installation errors
- **Site testing** to confirm anchors' suitability or correct installation