



X-BT-GR, X-BT-MR, X-BT-ER

**New Generation Hilti X-BT-GR,
X-BT-MR and X-BT-ER Threaded
Fastener Specification**



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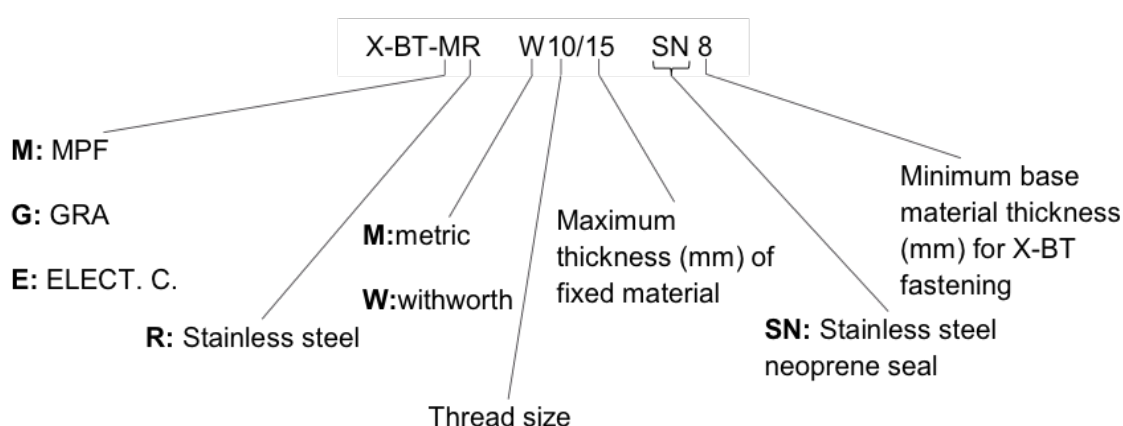
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GLOSSARY ON NEW PRODUCT DESIGNATION

- X- ... Letter indicating Direct Fastening DX solution
- BT... Blunt Tip stud
- G, M, E ... Grating fastener, Multi-purpose fastener or Electrical connector
- R ... identifies corrosion resistant material
- M6/W6/M8/M10/W10 ... thread type and size
- 3/7/10/14/15 ... maximum thickness of fixed material [mm]
- SN ... sealing washer with steel cap and neoprene rubber
- 8 ... minimum base material thickness [mm] without damage of backside coating

Example:



PREFACE TO THE NEW EDITION, JULY 2019

This new edition July 2019 is an update of the first edition of the "New Generation X-BT-GR, X-BT-MR and X-BT-ER Threaded Fastener Specification" from June 2018.

The main change is the addition of the new battery-actuated fastening tool BX 3-BT(G), which allows combustion free installation of the X-BT threaded fasteners. All performance data of the new generation X-BT threaded fasteners remain unchanged. A few more threaded fasteners with thread dimensions M6 and W6 were added to the fastener portfolio.

Since June 2018, several Type Approvals (DNV-GL, ABS, LR, BV) were granted for the new generation X-BT-GR, X-BT-MR and X-BT-ER threaded fasteners. Therefore, the section on approvals is also updated in this new edition July 2019. Specifically, the new section 5.4.3 was added to describe how the fatigue categories related with the detail "Structural steel base material with Hilti power-actuated fasteners X-BT-GR, X-BT-MR and X-BT-ER" were implemented in the several Type Approval Certificates.

PREFACE TO CHAPTER X-BT ON STRUCTURAL STEEL WITH PASSIVE FIRE PROTECTION (PFP) COATING, APRIL 2021

Section 5.12 includes information for fastening X-BT threaded studs with Hilti standoff adapter system for attaching instrumentation, junction boxes, lightning, installation channel systems etc. to steel with passive fire protection (PFP) coating.

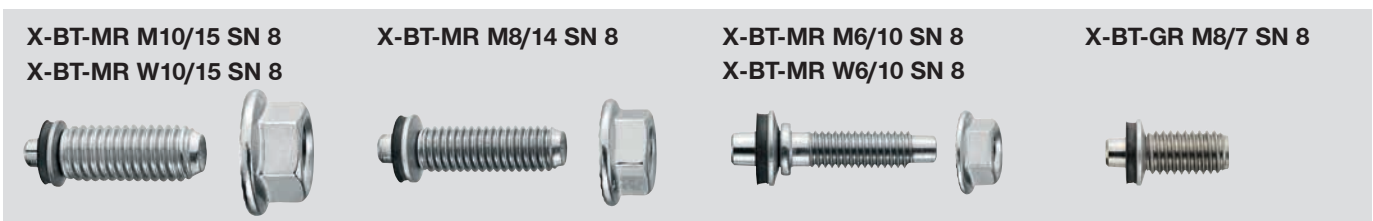
1. INTRODUCTION

1.1 Definitions and general terminology

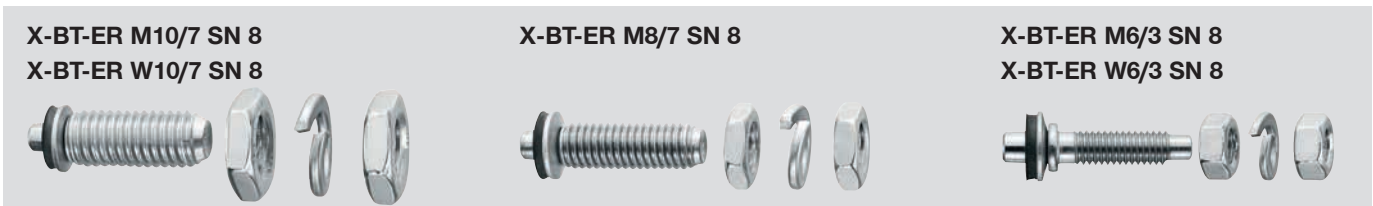
Hilti direct fastening technology is a technique in which specially hardened nails or studs are driven into steel, concrete or masonry by a piston-type tool. Materials suitable for fastening by this method are steel, wood, insulation and some kinds of plastic. Fastener driving power is generated by a power load (a cartridge containing combustible propellant powder, also known as a “booster”), combustible gas or by battery. During the driving process, base material is displaced and not removed. In Hilti terminology, DX stands for “powder-actuated” systems like the DX 351 BT(G), and BX stands for “battery-actuated” systems like the new BX 3-BT(G).

1.2 The new Generation X-BT system

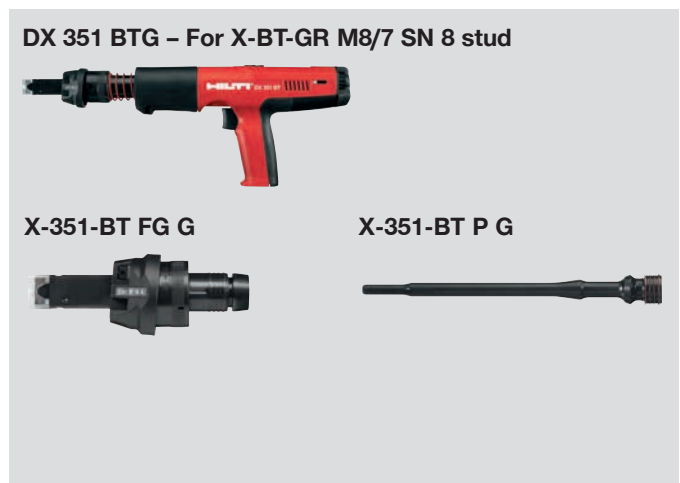
X-BT-GR for fastening of grating and X-BT-MR for multi-purpose fastenings



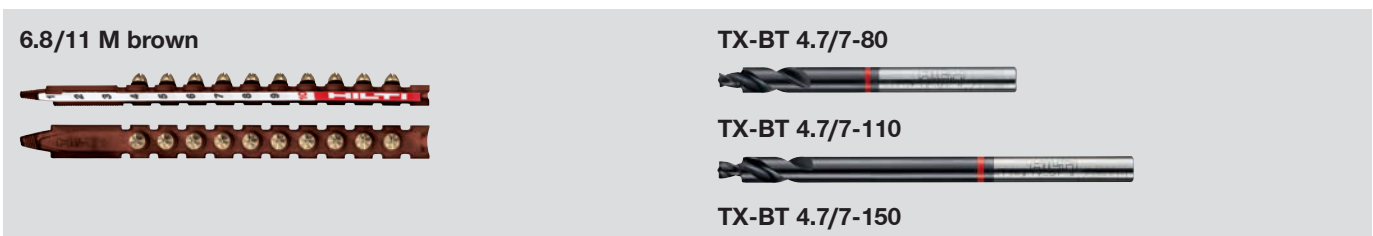
X-BT-ER stainless steel threaded stud for electrical connections



Tools and components

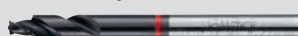


Cartridges and drill bits for DX



BX 3-BT – For X-BT-MR and X-BT-ER**X-FG B3-BT M****X-FG B3-BT W****BX 3-BTG – For X-BT-GR M8/7 SN 8 stud****X-FG B3-BTG****Battery and drill bits for BX****B 22/2.6**

Also allowed

B 22/3.0, B 22/4.0, B 22/5.2**TX-BT 4.7/7-80****TX-BT 4.7/7-110****TX-BT 4.7/7-150**

Since 2003 X-BT threaded fasteners have been successfully used in the market for applications in industrial and marine environment in the oil & gas as well construction industry. The new generation X-BT fasteners X-BT-GR, X-BT-MR and X-BT-ER – as presented in this document – replace the existing X-BT fasteners, which will be referenced in this document as "previous generation of X-BT fasteners". The table below shows the relationship between previous generation and the new generation products.

This specification of the new generation X-BT threaded fasteners builds on the comprehensive knowledge foundation established and proven for the previous X-BT generation. New technical content will be presented in this specification to support the increased tension, shear and bending resistance of the new generation X-BT studs. When appropriate, reference will be made to the knowledge foundation of the previous generation of X-BT fasteners.

Previous generation X-BT		New generation X-BT	
Item number	Designation	Item number	Designation
432266	Threaded stud X-BT M6-24-6 SN12-R	2252199	Threaded stud X-BT-MR M6/10 SN 8
432267	Threaded stud X-BT W6-24-6 SN12-R	2194337	Threaded stud X-BT-MR M6/14 SN 8 ¹⁾
N/A	N/A	2252470	Threaded stud X-BT-MR W6/10 SN 8
377078	Threaded stud X-BT M10-24-6 SN12-R	2194338	Threaded stud X-BT-MR W6/14 SN 8 ¹⁾
377076	Threaded stud X-BT W10-24-6 SN12-R	2194339	Threaded stud X-BT-MR M8/14 SN 8
377074	Threaded stud X-BT M8-15-6 SN12-R	2194340	Threaded stud X-BT-MR M10/15 SN 8
2107275	Electrical connector X-BT-ER M6/7 SN 4	2194341	Threaded stud X-BT-MR W10/15 SN 8
2103096	Electrical connector X-BT-ER W6/7 SN 4	2194344	Threaded stud X-BT-GR M8/7 SN 8
2103095	Electrical connector X-BT-ER M8/7 SN 4	2252195	Electrical connector X-BT-ER M6/3 SN 8
2103094	Electrical connector X-BT-ER M10/3 SN 4	2194349	Electrical connector X-BT-ER M6/7 SN 8 ¹⁾
2103093	Electrical connector X-BT-ER W10/3 SN 4	2252198	Electrical connector X-BT-ER W6/3 SN 8
		2194350	Electrical connector X-BT-ER W6/7 SN 8 ¹⁾
		2194351	Electrical connector X-BT-ER M8/7 SN 8
		2194352	Electrical connector X-BT-ER M10/7 SN 8
		2194353	Electrical connector X-BT-ER W10/7 SN 8

¹⁾ only for use with DX 351 BT



Rework



Corrosion



Through-penetration



Loosening

1.3 X-BT system features and benefits – simplified fastening to steel

No rework

Stud welding or through-bolting may require reworking of the protective surface coating. With X-BT, the stud is set into a small pre-drilled hole and the drill entry point is then completely sealed by the stud washer during setting.

Simple and fast

A minimal amount of training is all that's required for a user to be able to drive up to 100 studs per hour.

High corrosion resistance

X-BT studs are made of high grade 1.4462 stainless steel (at least equivalent to grade 316 or A4), making them the right choice for almost every corrosive environment.

High loading and pull-out values

X-BT delivers performance comparable to methods such as stud welding.

Fasten to all steel shapes

Unlike clamps, which are limited by the configuration of the base steel, the X-BT is ideal for use on hollow sections, channel sections, wide flanges and angles.

Fasten to all steel grades

In addition to fastening to standard construction steel, the X-BT can also be used to fasten to high strength and thick steel.

Portable

The fastening tool's self-contained energy source eliminates the need for electrical cords and heavy welding equipment.

No through-penetration

The special process of drilling and driving results in secure fastening of the stud without through-penetration of the base material.

1.4 Installation method and anchoring mechanism

The blunt-tipped new generation X-BT-GR, X-BT-MR and X-BT-ER threaded studs have a conical shank with a mean shank diameter of 5.2 mm and are driven into a pre-drilled 4.7 mm diameter hole. This leads to displacement of the base material. Part of the base steel is punched down into the pre-drilled hole, generating high temperatures and causing friction welding. Displaced base material can be seen in the photograph. Predominant anchorage mechanism is fusion of the stainless steel material with the base material. Base material adhering to the fastener shank observed from pullout tension tests clearly indicated the fusion (friction welding) effect.

(For more details regarding installation, please refer to section 4 – Method statement)



Displaced base material

1.5 Grating, multi-purpose and grounding applications

Metal / fiberglass grating to steel for upstream and high corrosion environment



- X-BT-GR M8
- X-FCM-R HL
- X-FCM-R
- X-FCS-R

Fastening Hilti MQ installation channel system, metal brackets, clips, metal tracks, etc. to steel



- X-BT-MR M10
- X-BT-MR W10
- X-BT-MR M8
- X-BT-MR M6
- X-BT-MR W6

Mechanical and electrical for petro chemical industry, shipbuilding, etc.



- X-BT-MR M10
- X-BT-MR W10
- X-BT-MR M8
- X-BT-MR M6
- X-BT-MR W6

Functional and protective bonding and lightning protection



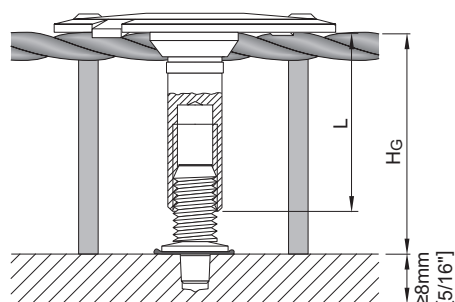
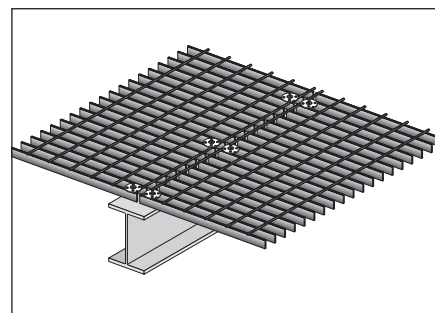
- X-BT-ER M10
- X-BT-ER W10
- X-BT-ER M8
- X-BT-ER M6
- X-BT-ER W6

2. APPLICATIONS

2.1 Grating fastening system

X-BT-GR M8/7 SN 8, X-FCM-R HL, X-FCM-R, X-FCS-R

An all stainless steel fastening system designed for attaching metal and fiberglass grating to coated steel and/or high-strength steel



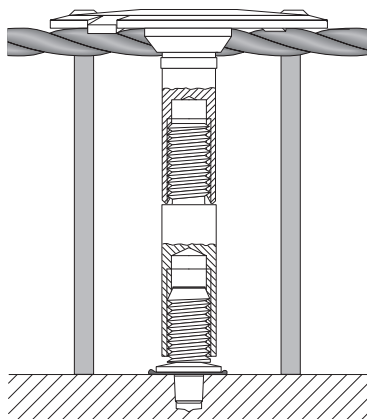
Thickness t of disc of X-FCM-R fasteners:
 X-FCM-R HL: t = 1.5 mm
 X-FCM-R: t = 1.25 mm

The X-FCM-R HL grating fastener allows higher tension and shear load resistance than the X-FCM-R grating fastener. The X-FCM-R HL grating fastener is designed to use the higher T of 20 Nm in combination with the new generation X-BT-GR M8/7 threaded stud.

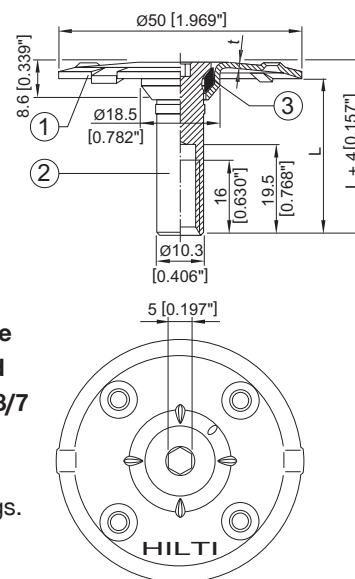
Note: The longer X-BT-MR M8/14 SN 8 is not intended to be used for grating fastenings.

X-SEA-R 30 M8 extension adaptor

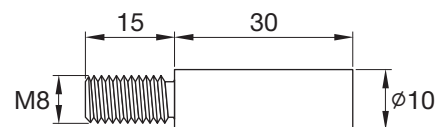
For use with X-FCM-R and X-FCM-R HL grating fasteners for fastening of grating with a height beyond 50 mm/1.97 in.



X-FCM-R (HL) grating disc



Outer diameter of the 2 tabs pressed into disc: 52 mm

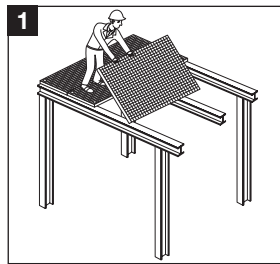


Fastener selection of X-FCM-R HL grating fasteners

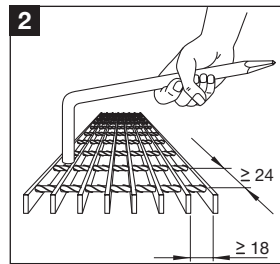
Designation	L (mm/in.)	Grating height, HG, range (mm/in.)	Grating height with X-SEA-R 30 M8
X-FCM-R HL 25/30	23/0.91	28 – 33/0.98 – 1.18	58 – 63/2.16 – 2.36
X-FCM-R HL 1"–1¼"	27/1.06	32 – 37/1.14 – 1.34	62 – 67/2.32 – 2.52
X-FCM-R HL 35/40	33/1.30	38 – 43/1.38 – 1.57	68 – 73/2.56 – 2.75
X-FCM-R HL 45/50	43/1.69	48 – 53/1.77 – 1.97	78 – 83/2.91 – 3.15

With regards to more details of X-FCM-R HL grating fasteners as well as details and product portfolio of the other grating fasteners X-FCM-R, X-FCM-M and X-FCS-R it is referred to the Hilti Direct Fastening Technology Manual.

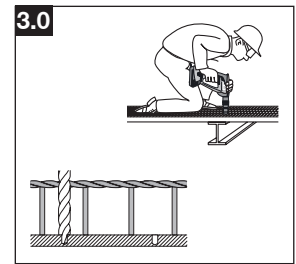
Installation instructions



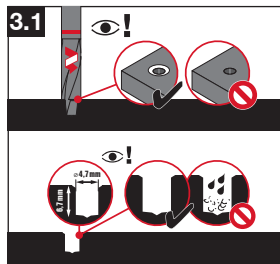
1 Lay grating section in final position.



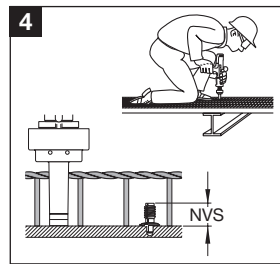
2 Expand grating openings if necessary.



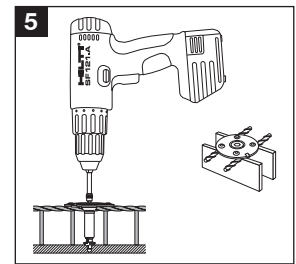
3.0 Pre-drill with **TX-BT 4.7/7** step shank drill bit.



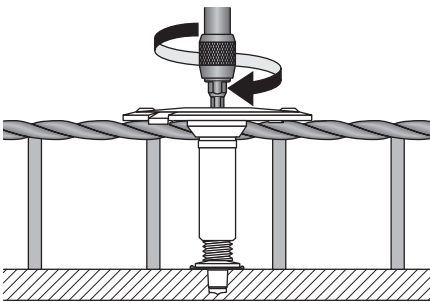
3.1 Pre-drill until shoulder grinds a shiny ring. The drill hole and the area around drilled hole must be clean and free from liquids and debris.



4 Drive fastener with **BX 3-BTG** tool or **DX 351 BT G** tool and 6.8/11 M brown cartridge.



5 Tighten **X-FCM-R (HL)** with 5 mm Allen-type bit.



Installation details

Hand start to ensure no cross threading, then tighten using screwdriver with torque clutch.

Tightening torque for X-FCM-R HL high load grating fasteners: $T = 20 \text{ Nm}$ [14.8 ft-lb]
 Tightening torque for X-FCM-R grating fasteners: $T = 5 - 8 \text{ Nm}$ [3.7 - 5.9 ft-lb]

Tightening tool:

- Screwdriver with torque release coupling (TRC)
- 5 mm Allen-type bit
- Hilti torque tool X-BT ¼" - 20 Nm [14.8 ft-lb]
- Hilti torque tool X-BT ¼" - 8 Nm

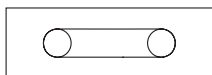
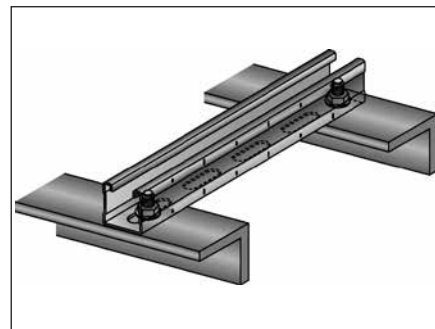
Hilti screwdriver

With regards to suitable Hilti screwdrivers and their torque settings see the information given in the Hilti Direct Fastening Technology Manual for the respective grating fasteners or the information given in the instruction for use which is supplied with the respective grating fastener.

2.2 X-BT and MQ installation channel system

MQ installation channel on coated steel (electrical installation and small-bore piping)

Note: In case of applied shear load, the X-BT should be placed according to illustration (end of slotted hole)

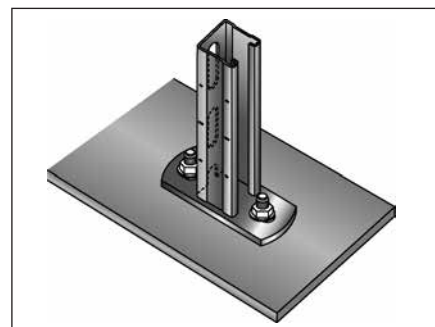
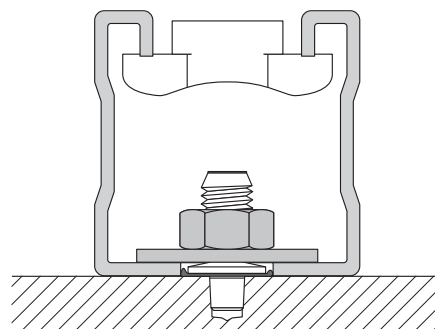


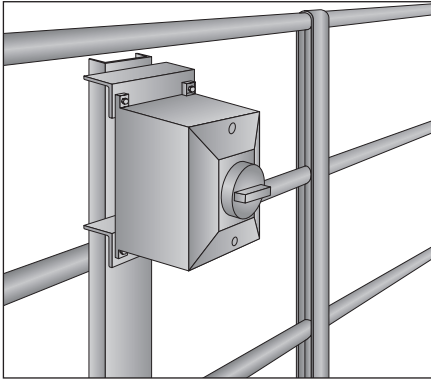
Two **X-BT** studs in one slotted hole



One **X-BT** stud in each slotted hole

Fastening MQ brackets and bases for raised floor

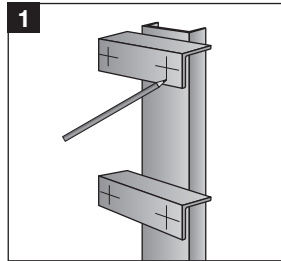




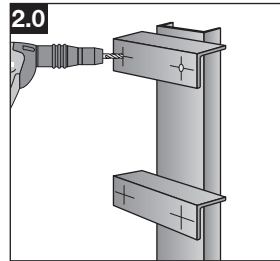
2.3 Fastening instrumentation, junction boxes and lighting

New generation X-BT stainless steel threaded stud for attaching instrumentation, junction boxes and lighting to coated steel and high-strength steel

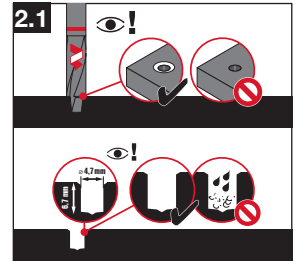
Installation instructions



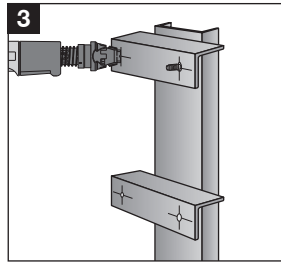
1
Mark location of each fastening.



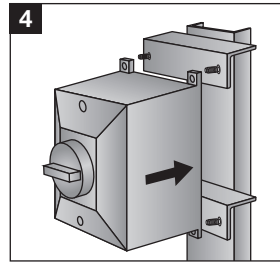
2.0
Pre-drill with **TX-BT 4.7/7** step shank drill bit.



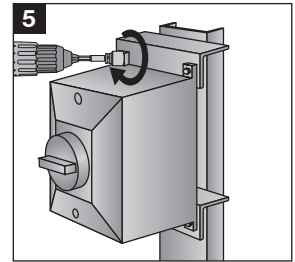
2.1
Pre-drill until shoulder grinds a shiny ring. The drill hole and the area around drilled hole must be clean and free from liquids and debris.



3
Drive X-BT fasteners with **BX 3-BT** tool or **DX 351 BT** tool and 6.8/11 M brown cartridge.



4
Position unit on studs and hold in place. Fit washers and start tightening by hand to avoid cross threading.

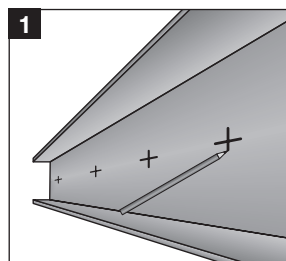


5
Tighten using a screwdriver with torque clutch or Hilti torque tool X-BT ¼" - 20 Nm [14.8 ft-lb]
T ≤ 20 Nm (≤ 14.8 ft-lb)

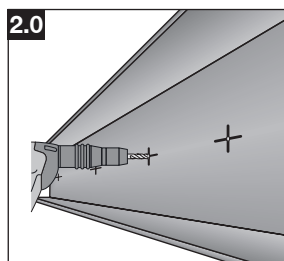
2.4 Fastening cable/conduit connectors

New generation X-BT threaded stud for cable/conduit connectors.
 Stainless steel threaded stud for fastening cable and conduit connectors (T-bars) to coated steel and/or high-strength steel

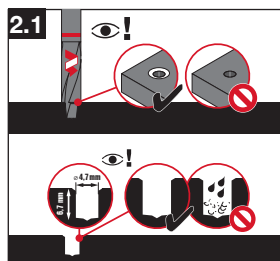
Installation instructions



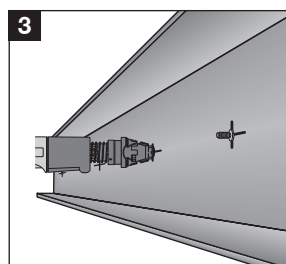
1 Mark location of each fastening.



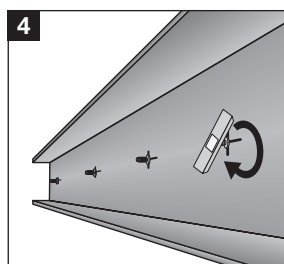
2.0 Pre-drill with **TX-BT 4.7/7** step shank drill bit.



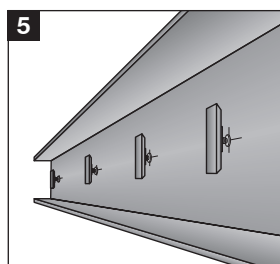
2.1 Pre-drill until shoulder grinds a shiny ring. The drill hole and the area around drilled hole must be clean and free from liquids and debris



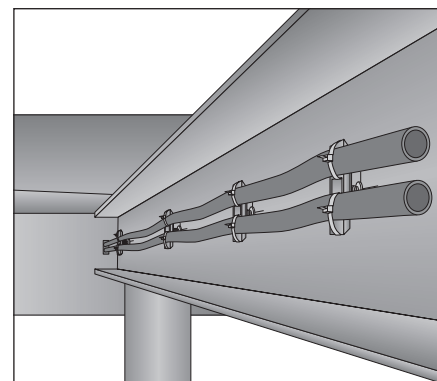
3 Drive X-BT fasteners with **BX 3-BT** tool or **DX 351 BT** tool and 6.8/11M brown cartridge.



4 Screw on the connector and hand tighten. $T \leq 20 \text{ Nm}$ ($\leq 14.8 \text{ ft-lb}$)



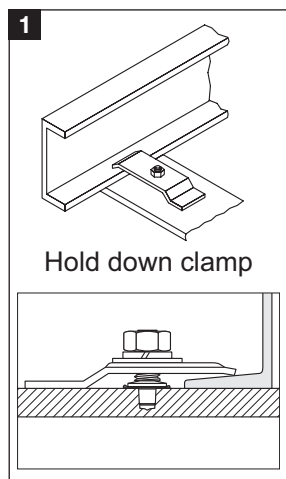
5 Align connectors.



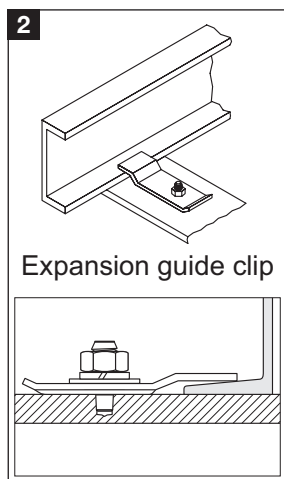
2.5 Fastening cable tray supports

New generation X-BT stainless steel stud for fastening cable trays to coated and / or high-strength steel

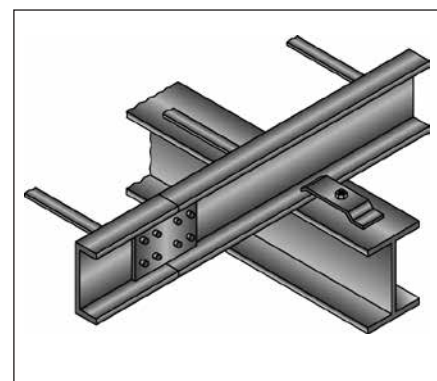
Installation instructions

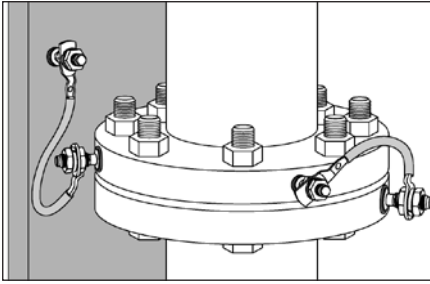


1 Hold down clamp



2 Expansion guide clip



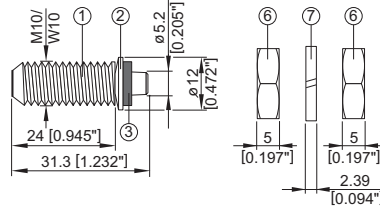


Functional and protective bonding in pipe (Outer diameter of installed surface ≥ 150 mm)

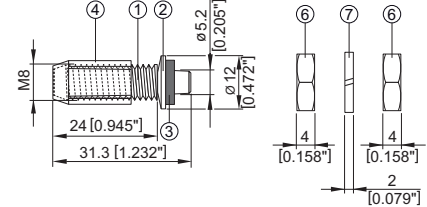
2.6 X-BT-ER electrical connectors

Fasteners

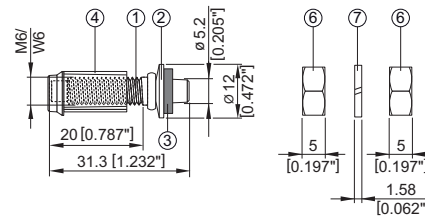
X-BT-ER M10/7 SN 8
X-BT-ER W10/7 SN 8



X-BT-ER M8/7 SN 8



X-BT-ER M6/3 SN 8
X-BT-ER W6/3 SN 8

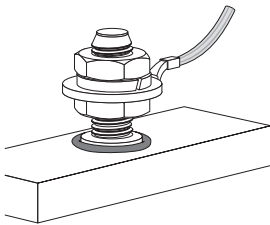


Please refer to Part 5.8.2 for additional technical information with regards to the effect of X-BT-ER fasteners on the integrity of pipe flange.

2.6.1 Functional bonding and terminal connection in a circuit

For low permanent current due to static charge built up in pipes or for low permanent current when closing an electrical circuit

Single point connection



Recommended electrical connectors:

- X-BT-ER M10/7 SN 8
- X-BT-ER W10/7 SN 8
- X-BT-ER M8/7 SN 8
- X-BT-ER M6/3 SN 8, X-BT-ER M6/7 SN 8
- X-BT-ER W6/3 SN 8, X-BT-ER W6/7 SN 8

Max. allowable permanent current = 40 A

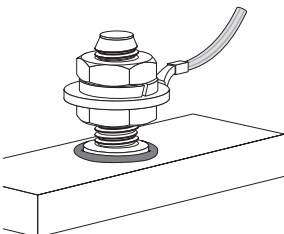
Note:

- Recommended connected cable size (tested to 40 A) according to IEC/EN 60204-1: ≤ 10 mm² copper (≤ 8 AWG). Fastening of thicker cable is acceptable provided the maximum permanent current of 40 A is not exceeded and the provisions on cable lug thickness are observed.

2.6.2 Protective bonding circuit

For discharging short circuit current while protecting electrical equipment or earth / ground or bond cable trays and ladders.

Single point connection



Recommended electrical connectors:

- X-BT-ER M10/7 SN 8
- X-BT-ER W10/7 SN 8
- X-BT-ER M8/7 SN 8
- X-BT-ER M6/3 SN 8, X-BT-ER M6/7 SN 8
- X-BT-ER W6/3 SN 8, X-BT-ER W6/7 SN 8

Max. short circuit current for period of 1s = 1250 A for single connection point

Note:

- Recommended connected cable size (tested to 1250 A for 1s) following IEC/EN 60947-7-2: ≤ 10 mm² copper (≤ 8 AWG). Fastening of thicker cable is acceptable provided the maximum current of 1250 A for a period of 1 second is not exceeded and the provisions on cable lug thickness are observed.
- Recommended connected cable size (tested to 750 A for 4s) according to UL 467: ≤ 10 AWG

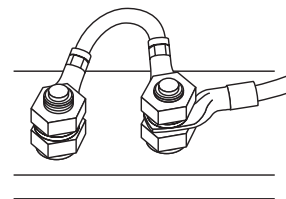
Recommended electrical connectors: Max. short circuit current for period of 1s = 1800 A for double point connection

- X-BT-ER M10/7 SN 8
- X-BT-ER W10/7 SN 8
- X-BT-ER M8/7 SN 8
- X-BT-ER M6/7 SN 8
- X-BT-ER W6/7 SN 8

Note:

- Recommended connected cable size (tested to 1800 A for 1s) following IEC/EN 60947-7-2: $\leq 16 \text{ mm}^2$ copper ($\leq 6 \text{ AWG}$). Fastening of thicker cable is acceptable provided the maximum current of 1800 A for a period of 1 second is not exceeded and the provisions on cable lug thickness are observed.

Double-point connection



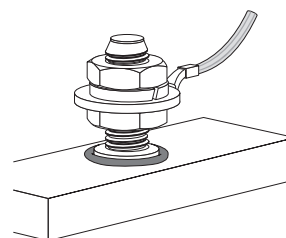
2.6.3 Lightning protection

For high temporary current due to lightning.

Recommended electrical connectors: Maximum test current (according to EN 62561-1:2012-01): $\leq 50 \text{ kA}$ for 2 ms

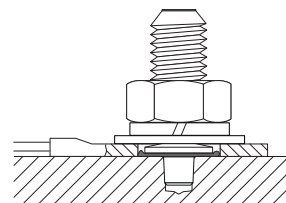
- X-BT-ER M10/7 SN 8
- X-BT-ER W10/7 SN 8
- X-BT-ER M8/7 SN 8
- X-BT-ER M6/3 SN 8, X-BT-ER M6/7 SN 8
- X-BT-ER W6/3 SN 8, X-BT-ER W6/7 SN 8

Single point connection



When one nut is utilized and cable lug is in contact with base material.

- Cable lug must be in direct contact with non-coated base material.
- Extra M10/W10 stainless steel washer to be used and installed between lock washer and cable lug.
- Base material must not contact the X-BT-ER SN washer, lock washer and nut.
- Cable lug thickness = 2 mm to 12 mm. Cable lug hole diameter $\geq 14 \text{ mm}$.
- Max. tightening torque = 20 Nm.



Recommended electrical connectors: Maximum test current $\leq 100 \text{ kA}$ for 2 ms

- X-BT-ER M10/7 SN 8
- X-BT-ER W10/7 SN 8
- X-BT-ER M8/7 SN 8
- X-BT-ER M6/3 SN 8, X-BT-ER M6/7 SN 8
- X-BT-ER W6/3 SN 8, X-BT-ER W6/7 SN 8

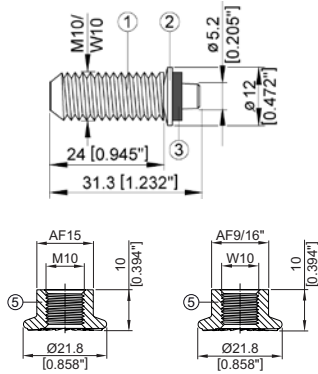
3. TECHNICAL DATA

3.1 Product data

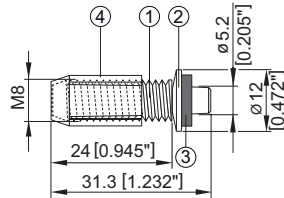
3.1.1 X-BT-GR and X-BT-MR material specification

- ① Shank and thread: S31803 (1.4462)
at least equivalent to A4 / AISI grade 316 material
- ② SN washers: S31635 (X2CrNiMo 17-12-2, 1.4404)
- ③ Sealing washers: Elastomer, black, resistant to UV, salt water, water, ozone, oils, etc.
- ④ Guiding sleeve: plastic
- ⑤ Flange nuts: A4 / AISI grade 316 material
Designation according to Unified Numbering System (UNS)

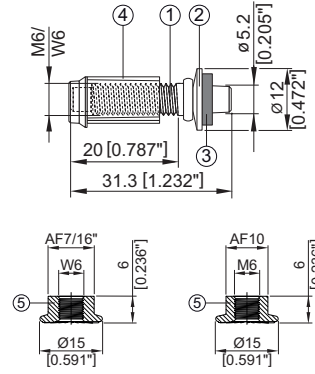
X-BT-MR M10/15 SN 8
X-BT-MR W10/15 SN 8



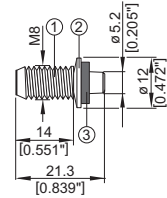
X-BT-MR M8/14 SN 8



X-BT-MR M6/10 SN 8
X-BT-MR W6/10 SN 8



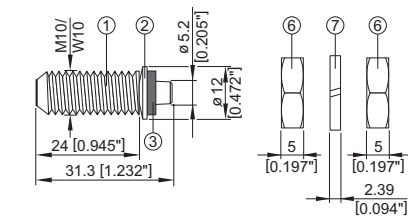
X-BT-GR M8/7 SN 8



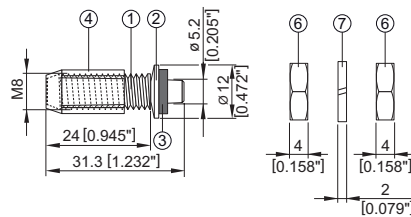
3.1.2 X-BT-ER material specifications

- ① Shank and thread: S31803 (1.4462)
at least equivalent to A4 / AISI grade 316 material
- ② SN washers: S31635 (X2CrNiMo 17-12-2, 1.4404)
- ③ Sealing washer: Elastomer, black, resistant to UV, salt water, water, ozone, oils, etc.
- ④ Guiding sleeve: plastic
- ⑤ Nuts: A4 / AISI grade 316 material
- ⑥ Lock washers: A4 / AISI grade 316 material

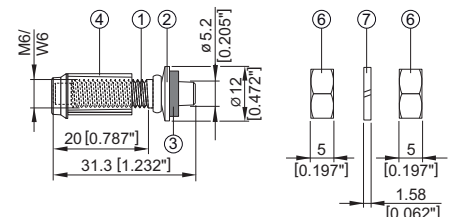
X-BT-ER M10/7 SN 8
X-BT-ER W10/7 SN 8



X-BT-ER M8/7 SN 8



X-BT-ER M6/3 SN 8
X-BT-ER W6/3 SN 8



3.1.3 Fastening tool

DX 351-BT / BTG, BX 3-BT / BTG, see fastener selection in section 3.3.5.

3.1.4 Approvals

ABS, DNV, GL, LR, ICC ESR-2347, UL



The previous X-BT threaded fastener generation as described in the Hilti X-BT Threaded Fastener Specification – July 2015 holds for many years several Type Approvals which are valid for the ship-building and off-shore industry.

These bodies are:

- ABS – American Bureau of Shipping
- DNVGL – Det Norske Veritas – Germanischer Lloyd
- LR – Lloyds Register
- BV – Bureau Veritas
- Russian Maritime Register

The ICC-ES approval ESR-2347 covers application of the X-BT in building construction. ESR-2347 allows for the use of X-BT in compliance with the 2015 International Building Code (2015 IBC).

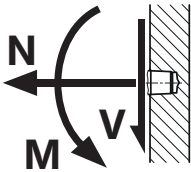
The UL-listing (File E257069) addresses the use of X-BT-ER as grounding and bonding equipment.

The New Generation X-BT-GR and X-BT-MR fasteners also hold the following separate Type Approvals:

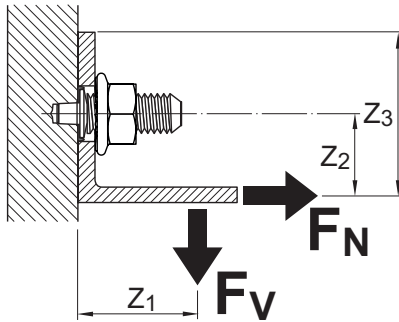
- ABS 18-HS1755518
- DNV-GL TAS00001SV
- BV 54554
- LR 19/0003

Furthermore, the New Generation X-BT-GR and X-BT-MR fasteners were added into ICC-ES ESR-2347 and the new X-BT-ER were also added into UL-file E257067.

Approvals can also be downloaded from Hilti website or from the websites of most Certification Bodies.



Example:



Provisions for group fastenings

For group fastenings with up to 4 fasteners per group and shear force introduction via the sealing washer (section 5.2.3), the resistance of all fastener can be added up, provided the hole in the fastened material is equal or less than 14 mm (e.g. $V_{rec,group} = 17.2$ kN for a group with 4 fasteners fixed to S235 base material).

3.2 Load data

3.2.1 Loads – Construction steel

Recommended loads – steel base material

Steel grades:	S235, S275, A36	S355 to S960 \geq Grade 50
Tension, N_{rec} [kN/lb]	3.6 / 810	4.6 / 1030
Shear, V_{rec} [kN/lb]	4.3 / 970	5.3 / 1190
Moment, M_{rec} [Nm/ft-lb]	20.0 / 14.8	20.0 / 14.8
Torque, T_{rec} [Nm/ft-lb]	20.0 / 14.8	20.0 / 14.8

Conditions for recommended loads

- Application of working load design concept (e.g. ASD).
- For unalloyed construction, off-shore and Shipbuilding steel: e.g. European grades according to EN 10025-4 or EN 10225, S690Q and S960Q according to EN 10025-6, US steel grade A36 and Grade 50.
- Minimum base material thickness $t_{II} = 8$ mm.
- Applicable for steel base materials up to a coating thickness of 500 μ m.
- Edge distance $c \geq 10$ mm [3/8"].
- In case of edge distance 6 mm $\leq c < 10$ mm, N_{rec} , V_{rec} and M_{rec} need to be reduced with the reduction factor $\alpha_c = 0.65$.
- Redundancy (multiple fastening) must be provided.

Remarks

- The recommended loads in the table refer to the resistance of the single fastener and need to be determined by static analysis from the loads F_N and F_V acting on the fastened part. Typical example is the need of consideration of prying forces, see example.
- Moments acting on the shank only need to be considered in case of a gap between the base and the fastened material.
- Global factor of safety for tension and shear load = 2.8 related to the characteristic resistance N_{Rk} and V_{Rk} .
- Global factor of safety for bending moment = 1.75 related to the characteristic plastic moment M_{Rk} of the shank.
- Effects of base metal vibration and stresses are considered.

Characteristic resistance – steel base material

Steel grades	S235, S275, A36	S355 to S960, \geq Grade 50
Tension, N_{Rk} [kN/lbs]	10.0 / 2240	13.0 / 2920
Shear, V_{Rk} [kN/lbs]	12.0 / 2700	15.0 / 3360
Moment, M_{Rk} [Nm/ft-lb]	35.0 / 25.5	35.0 / 25.5

Design resistance - steel base material

Steel grades	S235, S275, A36	S355 to S960, \geq Grade 50
Tension, N_{Rd} [kN/lbs]	5.0 / 1120	6.5 / 1460
Shear, V_{Rd} [kN/lbs]	6.0 / 1350	7.5 / 1680
Moment, M_{Rd} [Nm/ft-lb]	28.0 / 20.5	28.0 / 20.5

Supplemental conditions and remarks for design resistances

- Application of partial safety design concept (e.g. Eurocode steel design)
- Design resistances N_{Rd} and V_{Rd} are determined from the characteristic resistance N_{Rk} and V_{Rk} applying a partial safety factor $\gamma_M = 2.0$
- Design resistance M_{Rd} is determined from the characteristic resistance M_{Rk} applying a partial safety factor $\gamma_M = 1.25$

3.2.2 Loads – cast iron base material*

Recommended loads – cast iron base material*

Tension,	N_{rec} [kN/lb]	1.0 / 230
Shear,	V_{rec} [kN/lb]	1.5 / 340
Moment,	M_{rec} [Nm/ft-lb]	16.0 / 11.5

Design resistance – cast iron*

Tension,	N_{Rd} [kN/lbs]	1.6 / 360
Shear,	V_{Rd} [kN/lbs]	2.4 / 540
Moment,	M_{Rd} [Nm/ft-lb]	26.0 / 19.0

*Requirements of spheroidal graphite cast iron base material

Subject	Requirements
Cast iron	Spheroidal graphite cast iron according to EN 1563
Strength class	EN-GJS-400 to EN-GJS-600 according to EN 1563
Chemical analysis and amount of carbon	3.3 - 4.0 mass percentage
Microstructure	From IV to VI (spherical) according to EN ISO 945-1:2010 Minimum size 7 according to figure 4 of EN ISO 945-1:2010
Material thickness	$t_{II} \geq 20$ mm

Recommended interaction formula for combined loading - steel and cast iron base material

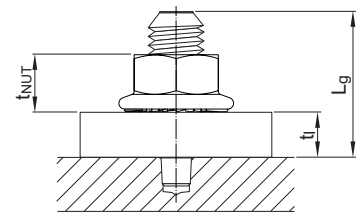
Load combination	Interaction provision
Shear - Tension	$\frac{V_{Sd}}{V_{Rd}} + \frac{N_{Sd}}{N_{Rd}} \leq 1.2$ with $\frac{V_{Sd}}{V_{Rd}} \leq 1.0$ and $\frac{N_{Sd}}{N_{Rd}} \leq 1.0$
Shear - Bending moment	$\frac{V_{Sd}}{V_{Rd}} + \frac{M_{Sd}}{M_{Rd}} \leq 1.2$ with $\frac{V_{Sd}}{V_{Rd}} \leq 1.0$ and $\frac{M_{Sd}}{M_{Rd}} \leq 1.0$
Tension - Bending moment	$\frac{N_{Sd}}{N_{Rd}} + \frac{M_{Sd}}{M_{Rd}} \leq 1.0$
Shear - Tension - Bending moment	$\frac{V_{Sd}}{V_{Rd}} + \frac{N_{Sd}}{N_{Rd}} + \frac{M_{Sd}}{M_{Rd}} \leq 1.0$

3.3 Application requirements and limits

3.3.1 Thickness of fastened material – X-BT-MR

- X-BT-GR M8: $2.0 \leq t_1 \leq 7 \text{ mm}$
- X-BT-MR M10/W10: $2.0 \leq t_1 \leq 15 \text{ mm}$
- X-BT-MR M8: $2.0 \leq t_1 \leq 14 \text{ mm}$
- X-BT-MR M6/W6: $2.0 \leq t_1 \leq 10 \text{ mm}^x)$

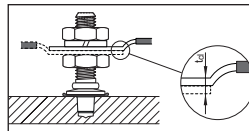
^{x)} If base material sits on the collar of the stud $t_{1,\min} = 1.0 \text{ mm}$



3.3.2 Thickness of cable lug – X-BT-ER

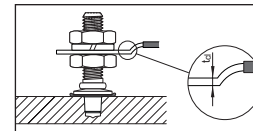
- X-BT-ER M8/M10/W10
- X-BT-ER M6/W6 /7 SN 8

$t_{cl} \leq 7 \text{ mm (0.28")}$



- X-BT-ER M8/M10/W10
- X-BT-ER M6/W6 /7 SN 8
- X-BT-ER M6/W6 /3 SN 8

$t_{cl} \leq 3 \text{ mm (0.12")}$



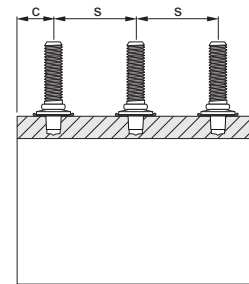
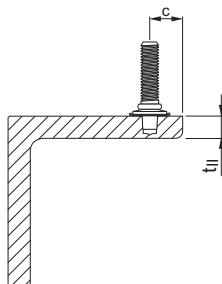
3.3.3 Spacing and edge distances

Edge distance:

- $c \geq 10 \text{ mm}$ (load reduction factor $\alpha_c = 1.00$)
- $6 \text{ mm} \leq c < 10 \text{ mm}$ (load reduction factor $\alpha_c = 0.65$)

Spacing:

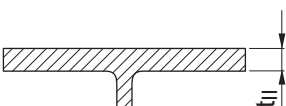
- $s \geq 15 \text{ mm}$



Outer diameter of installed surface (e.g. pipe flange) $\geq 150 \text{ mm}$

3.3.4 Application limit/thickness of base material

$t_{11} \geq 8 \text{ mm [5/16"]}$ → No through-penetration. No limits with regard to steel strength.



3.3.5 Fastener selection and DX 351 fastening system components

Fastener	Item number	Fastening tool	Fastening tool components	Cartridge	Step shank drill bit	
X-BT-GR M8/7 SN 8	2194344	Tool: DX 351 BTG	Fastener guide: X-351-BT FG G (item no: 378675) Piston: X-351-BT P G (item no: 378677)	6.8/11 M brown High Precision (item no: 412689)	TX-BT 4.7/7-80 (item no: 2197930) TX-BT 4.7/7-110 (item no: 2197931) TX-BT 4.7/7-150 (item no: 2197629)	
X-BT-MR M10/15 SN 8	2194340	Tool: DX 351 BT	Fastener guide: X-351-BT FG M1024 (item no: 378674)			
X-BT-MR M8/14 SN 8	2194339		Piston: X-351-BT P 1024 (item no: 378676)			
X-BT-MR M6/10 SN 8	2252199		Fastener guide: X-351-BT FG W1024 (item no: 378673)			
X-BT-MR M6/14 SN 8	2194337					Piston: X-351-BT P 1024 (item no: 378676)
X-BT-MR W10/15 SN 8	2194341					Fastener guide: X-351-BT FG W1024 (item no: 378673)
X-BT-MR W6/10 SN 8	2252470					
X-BT-MR W6/14 SN 8	2194338	Tool: DX 351 BT	Fastener guide: X-351-BT FG M1024 (item no: 378674)			
X-BT-ER M10/7 SN 8	2194352		Piston: X-351-BT P 1024 (item no: 378676)			
X-BT-ER M8/7 SN 8	2194351		Fastener guide: X-351-BT FG W1024 (item no: 378673)			
X-BT-ER M6/3 SN 8	2252195					Piston: X-351-BT P 1024 (item no: 378676)
X-BT-ER M6/7 SN 8	2194349					Fastener guide: X-351-BT FG W1024 (item no: 378673)
X-BT-ER W10/7 SN 8	2194353		Piston: X-351-BT P 1024 (item no: 378676)			
X-BT-ER W6/3 SN 8	2252198			Fastener guide: X-351-BT FG W1024 (item no: 378673)		
X-BT-ER W6/7 SN 8	2194350	Piston: X-351-BT P 1024 (item no: 378676)				

Note:

The three step shank drills only differ in their length. Their use depends on the accessibility condition on the jobsite.

6.8/11 M high-precision brown cartridge

The recommended tool energy setting = 1 (if required, increase of energy setting based on job site tests).

3.3.6 Fastener selection and BX 3 fastening system components

Fastener	Item number	Fastening tool	Fastening tool components	Energy	Step shank drill bit
X-BT-GR M8/7 SN 8	2194344	Tool: BX 3-BTG	Fastener guide: X-FG B3-BTG (item no: 2197625)	Hilti's 22V cordless tool battery platform	TX-BT 4.7/7-80 (item no: 2197930) TX-BT 4.7/7-110 (item no: 2197931) TX-BT 4.7/7-150 (item no: 2197629)
X-BT-MR M10/15 SN 8	2194340	Tool: BX 3-BT	Fastener guide: X-FG B3-BT M (item no: 2197626)		
X-BT-MR M8/14 SN 8	2194339				
X-BT-MR M6/10 SN 8	2252199		Fastener guide: X-FG B3-BT W (item no: 2197627)		
X-BT-MR W10/15 SN 8	2194341				
X-BT-MR W6/10 SN 8	2252470				
X-BT-ER M10/7 SN 8	2194352	Tool: BX 3-BT	Fastener guide: X-FG B3-BT M (item no: 2197626)		
X-BT-ER M8/7 SN 8	2194351				
X-BT-ER M6/3 SN 8	2252195		Fastener guide: X-FG B3-BT W (item no: 2197627)		
X-BT-ER W10/7 SN 8	2194353				
X-BT-ER W6/3 SN 8	2252198				

Note:

The three step shank drills only differ in their length. Their use depends on the accessibility condition on the jobsite.

The fastener guides of the battery-actuated tool BX 3-BT(G) also allow embedment depth adjustment:

The front part can be turned to the positions 1, 2, 3 or 4 (Higher position leads to deeper embedment). The recommended start position is 3. If required, fine adjustment during job-site execution be applied.

Complementary information for use of BX 3-BT(G) battery-actuated fastening tool in combination with previous generation X-BT threaded fasteners

The battery-actuated fastening tool BX 3-BT(G) is also suitable to drive the following previous generation X-BT threaded fasteners. The drilled holes have to be made with the previous generation step shank drill bits TX-BT 4/7. The corresponding allocation of system components is summarized in the table below:

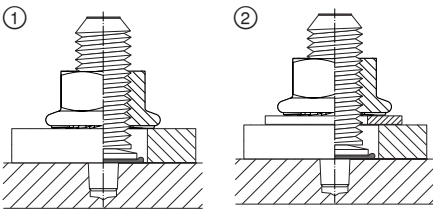
BX 3-BT(G) Fastener Guide	Previous Generation X-BT threaded fasteners	Previous generation step shank drill bits
X-FG B3-BTG (item no: 2197625)	X-BT M8-15-6 SN12-R (item no: 377074)	
X-FG B3-BT M (item no: 2197626)	X-BT M10-24-6 SN12-R (item no: 377078)	TX-BT 4/7-80 (item no: 377079)
	X-BT-ER M10/3 SN 4 (item no: 2103094)	TX-BT 4/7-110 (item no: 377080)
	X-BT-ER M8/7 SN 4 (item no: 2103095)	TX-BT 4/7-150 (item no: 377081)
X-FG B3-BT W (item no: 2197627)	X-BT W10-24-6 SN12-R (item no: 377076)	
	X-BT-ER W10/3 SN 4 (item no: 2103093)	

For the listed previous generation X-BT threaded fasteners, the same technical performance data as described in section 3 of the "Hilti X-BT Threaded Fastener Specification, July 2015" applies, when the BX 3-BT(G) is used to drive the above fasteners.

The previous generation X-BT threaded fasteners also hold the following separate Type Approvals:

- ABS 16-HS1545448-PDA
- DNV-GL 12272-10HH
- BV 23498/B0 BV
- LR 03/00070(E4)

3.3.7 Installation details – X-BT-MR



X-BT-MR M8

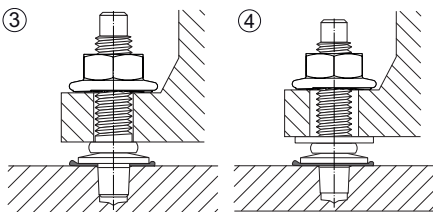
Fastened material:

- Hole diameter: 13 to 14 mm: Use of supplied flange nut ①
- Hole diameter: beyond 14 to 18 mm: Use of supplied flange nut with supplement washer (maximum thickness of fixed component to be reduced with thickness of washer) ②

X-BT-MR M10/W10

Fastened material:

- Hole diameter: 13 to 18 mm: Use of supplied flange nut ①
- Hole diameter: beyond 18 to 22 mm: Use of supplied flange nut with supplement washer (maximum thickness of fixed component to be reduced with thickness of washer) ②



X-BT-MR M6/W6

Fastened material:

- Hole diameter: 6.5 – 6.7: Fastener sits on collar of stud, use of supplied flange nut ③
- Hole diameter: 6.7 to 11 mm: Use of supplied flange nut with supplement washer sitting on collar ④
- Hole diameter: > 12 mm, fixed part sits on base material, use of flange nut with supplemental washer to cover hole clearance (maximum thickness of fixed component to be reduced with thickness of washer) ②

Provisions on group fastenings

For group fastenings with up to 4 fasteners per group and shear force introduction via the sealing washer (section 5.2.3), the resistance of all fasteners can be added up, provided the hole in the fastened material is equal or less than 14 mm.

For hole diameters in the fastened material greater than 14 mm, the following conservatively applies:

- For the shear load transfer only one fastener of the group may be considered (e.g. $V_{rec,group} = 4,3 \text{ kN}$ for any fastener group with ≥ 2 fasteners in S235 base material).
- If relevant, deformations have to be checked for serviceability reasons.

Before fastener installation

The drilled hole must be clear of liquids and debris. The area around the drilled hole must be free from liquids and debris.

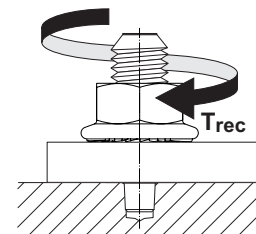


Pre-drill until the bit shoulder grinds a shiny ring (to ensure proper drilling depth).

Remark: Recommended tightening torque for thin base material thickness $4 \leq t_{II} < 8 \text{ mm}$, see section 5.11.

Tightening torque, $T_{rec} \leq 20 \text{ Nm}$ [14.8 ft-lb]

Hilti torque tool $\frac{1}{4}''$ - 20 Nm / [14.8 ft-lb]

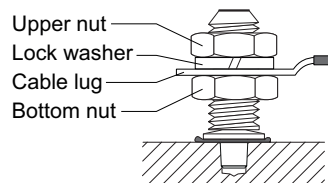
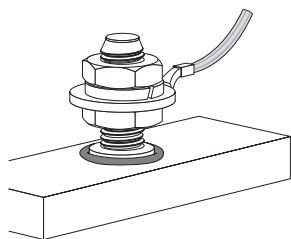


Hilti screwdriver

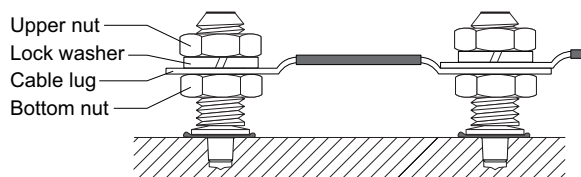
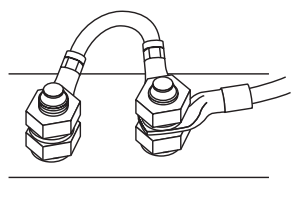
With regards to suitable Hilti screwdrivers and their respective torque settings see the information given in the Hilti Direct Fastening Technology Manual or the information given in the instruction for use which are supplied with the fasteners.

3.3.8 Installation for electrical connections – X-BT-ER

Single point connection for all X-BT-ER M8/M10/W10 /7 SN 8,
X-BT-ER M6/W6 /3 SN 8



Double point connection for all X-BT-ER M8/M10/W10 /7 SN 8,
X-BT-ER M6/W6 /7 SN 8



3.3.9 Fastening quality assurance

Fastening inspection

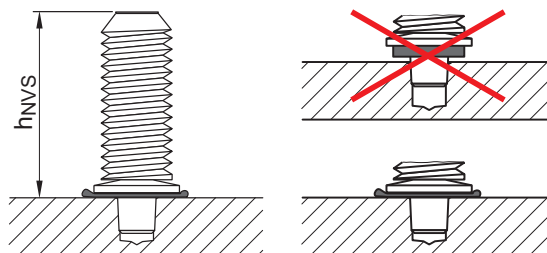
X-BT-GR M8

$h_{NVS} = 15.7 - 16.8 \text{ mm}$

X-BT-MR M6/W6/M8/M10/W10

X-BT-ER M6/W6/M8/M10/W10

$h_{NVS} = 25.7 - 26.8 \text{ mm}$



4. METHOD STATEMENT

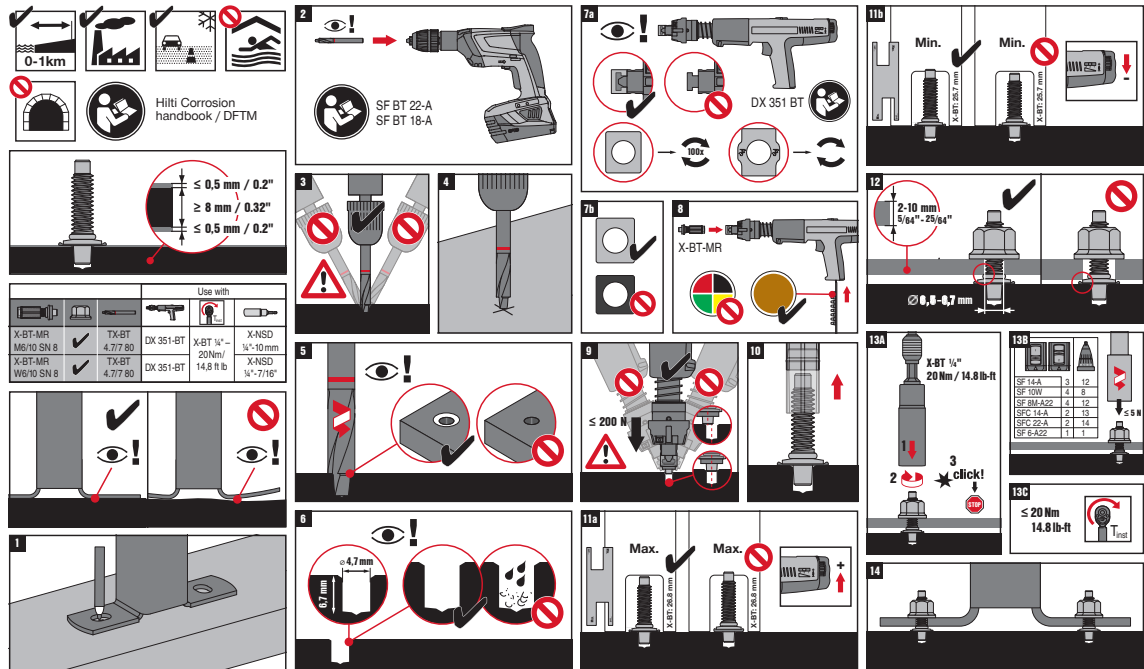
4.1 Instructions for use - X-BT-MR M6/W6/10 SN 8

Fastening tool: DX 351



X-BT-MR M6/W6

2259050 A1-07 2019

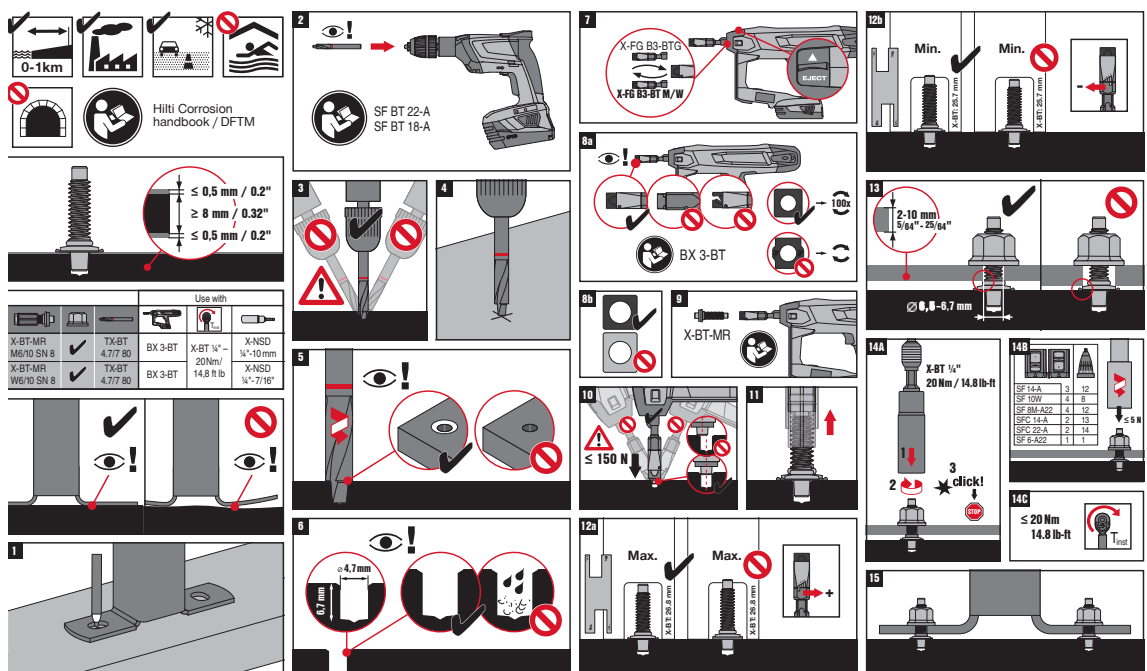


For fasteners X-BT-MR M6/14 SN 8 and X-BT-MR W6/14 SN 8 the same instructions for use apply with the exception of the maximum thickness of the fixed component, for detail it is referred to the instructions supplied with each box of fasteners.

Fastening tool: BX 3



X-BT-MR M6/W6



Instructions for use are subject to continuous changes related to code developments, product portfolio updates, and new research results. Current instruction for use can be downloaded from Hilti website.

4.2 Instructions for use - X-BT-MR M8/14 SN 8

Fastening tool: DX 351



X-BT-MR M8

2203795 A2-07.2019

Use with	
X-BT-MR M8/14 SN 8	TX-BT 4.7/7.80
DX 351-BT	X-BT 1/4" 20Nm / 14.8 lb-ft
S-NS 15 C 95/3 1/4"	

Use with	
X-BT-MR M8/14 SN 8	TX-BT 4.7/7.80
BX 3-BT	X-BT 1/4" 20Nm / 14.8 lb-ft
S-NS 15 C 95/3 1/4"	

Fastening tool: BX 3



X-BT-MR M8

Use with	
X-BT-MR M8/14 SN 8	TX-BT 4.7/7.80
BX 3-BT	X-BT 1/4" 20Nm / 14.8 lb-ft
S-NS 15 C 95/3 1/4"	

Use with	
X-BT-MR M8/14 SN 8	TX-BT 4.7/7.80
BX 3-BT	X-BT 1/4" 20Nm / 14.8 lb-ft
S-NS 15 C 95/3 1/4"	

Instructions for use are subject to continuous changes related to code developments, product portfolio updates, and new research results. Current instruction for use can be downloaded from Hilti website.

4.3 Instructions for use - X-BT-MR M10/W10/15 SN 8

Fastening tool: DX 351



X-BT-MR M10/W10

2203796 A2-07_2019

	TX-BT	TX-BT	Use with
X-BT-MR M10/15 SN 8	✓	4.7/7 80	DX 351-BT X-BT 1/4" - 20Nm/ 14.8 ft lb S-NIS15 C 95/3 1/4"
X-BT-MR W10/15 SN 8	✓	4.7/7 80	DX 351-BT X-BT 1/4" - 20Nm/ 14.8 ft lb S-NIS 9/4" C 95/3 1/4"

	SF 14-A	SF 10W/ BM-A22	SFC 14.22-A	SF 6-A22
3	13	4	11	11

Fastening tool: BX 3



X-BT-MR M10/W10

	TX-BT	TX-BT	Use with
X-BT-MR M10/15 SN 8	✓	4.7/7 80	BX 3-BT X-BT 1/4" - 20Nm/ 14.8 ft lb S-NIS15 C 95/3 1/4"
X-BT-MR W10/15 SN 8	✓	4.7/7 80	BX 3-BT X-BT 1/4" - 20Nm/ 14.8 ft lb S-NIS 9/4" C 95/3 1/4"

	SF 14-A	SF 10W/ BM-A22	SFC 14.22-A	SF 6-A22
3	13	4	11	11

Instructions for use are subject to continuous changes related to code developments, product portfolio updates, and new research results. Current instruction for use can be downloaded from Hilti website.

4.4 Instructions for use - X-BT-GR M8/7 SN 8

Fastening tool: DX 351



X-BT-GR M8

2203797 A2-07.2019

Fastening tool: BX 3



X-BT-GR M8

Instructions for use are subject to continuous changes related to code developments, product portfolio updates, and new research results. Current instruction for use can be downloaded from Hilti website.

4.5 Instructions for use - X-BT-ER M8/M10/W10 SN 8

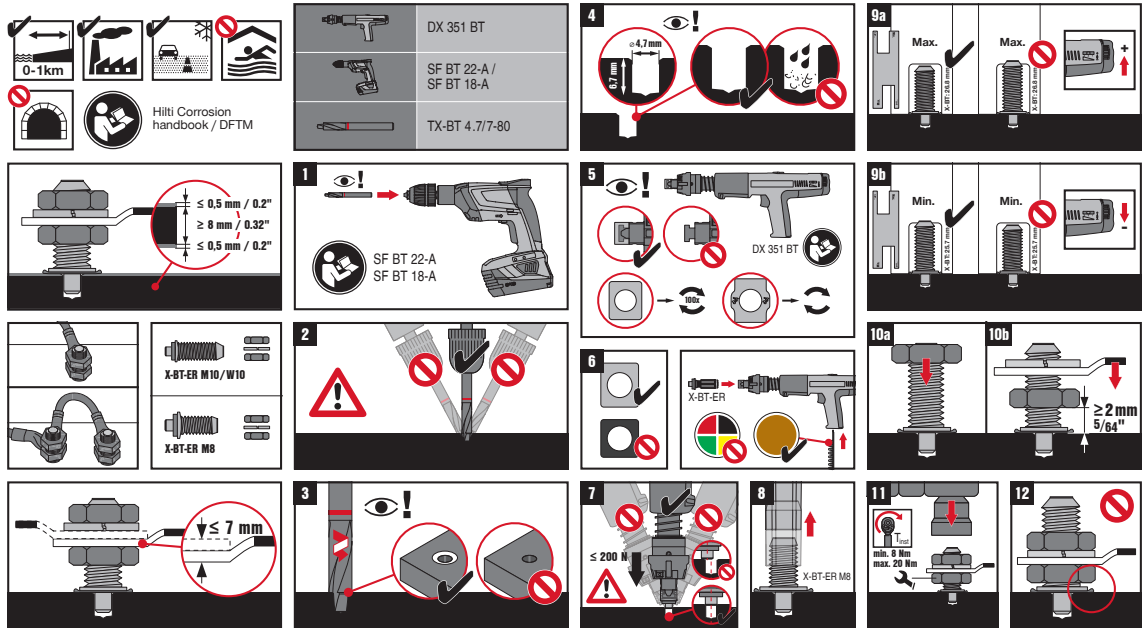
The following graphs show the instructions for use for the items X-BT-ER M8/M10/W10 /7 SN 8. Instructions for use related with X-BT-ER M6/W6 /3 SN 8 are provided in the X-BT packages.

Fastening tool: DX 351



X-BT-ER M8,
M10/W10 SN 8

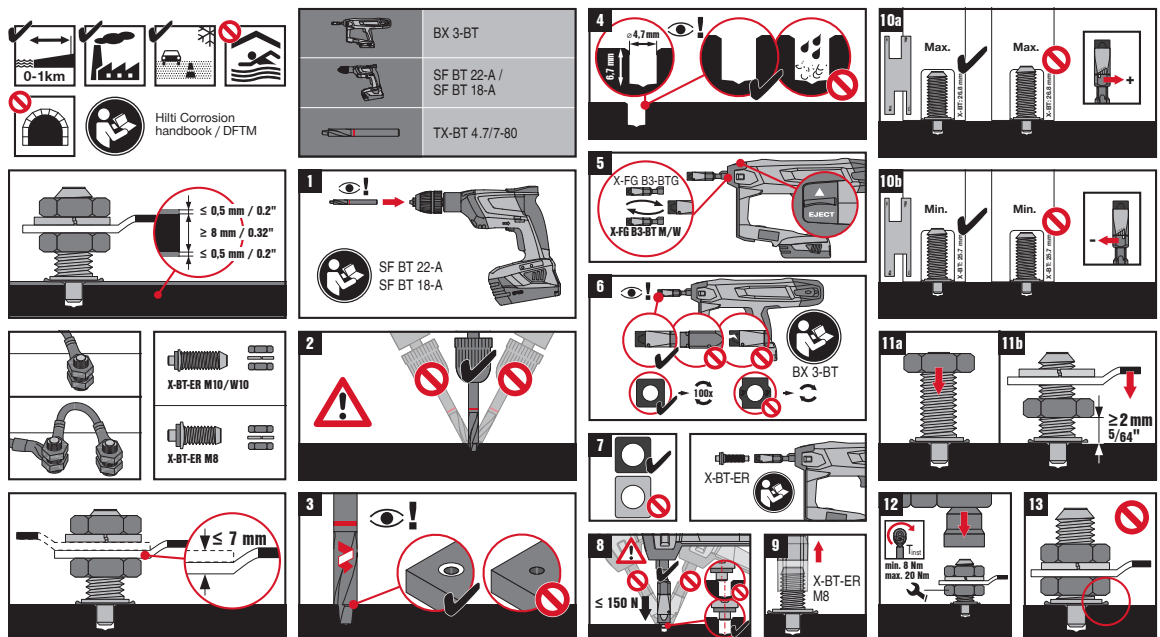
2197511 A2-07.2019



Fastening tool: BX 3



X-BT-ER M8,
M10/W10 SN 8



Instructions for use are subject to continuous changes related to code developments, product portfolio updates, and new research results. Current instruction for use can be downloaded from Hilti website.

5. PERFORMANCE (TECHNICAL REPORTS)

5.1 Nomenclature and symbols, design concepts

The symbols and nomenclature used in the technical data are listed below.

Fastener test data and performance

N and V	Tensile and shear forces in a general sense
F	Combined force (resulting from N and V) in a general sense
N_{Sk} and V_{Sk}	Characteristic tensile and shear forces (actions) acting on a fastening in a design calculation
N_{Sd} and V_{Sd}	Design tensile and shear forces (actions) acting on a fastening in a design calculation
N_u and V_u	Ultimate tensile and shear forces that cause failure of the fastening, statistically, the reading for one specimen
N_{u,m} and V_{u,m}	Average ultimate tensile and shear forces that cause failure of the fastening, statistically, the average for a sample of several specimens
s	The standard deviation of the sample
N_{Rk} and V_{Rk}	Characteristic tensile and shear resistance of the fastening, statistically, the 5%-fractile. For example, the 5%-fractile strength of a fastening whose ultimate strength can be described by a standard Gauss type distribution is calculated per test series by: $N_{5\%,t} = N_{u,m} - k \times s$ where k is a function of the sample size and the desired confidence level
N_{Rd} and V_{Rd}	Tensile and shear design resistance of the fastener
N_{rec} and V_{rec}	Recommended maximum tensile and shear loads of the fastener
M_{rec}	Recommended working moment of the fastener (statistically derived from the characteristic bending resistance M_{Rk})

Fastening details

h_{ET}	Penetration of the fastener point below the surface of the base material
h_{NVS}	Fastener standoff above the surface fastened into
t_{II}	Thickness of the base material
t_i	Thickness of the fastened material
$\sum t_i$	Total thickness of the fastened material (where more than one layer is fastened)
t_{cl}	Total thickness of cable lug (for X-BT-ER)

Characteristics of steel and other metals

f_y and f_u	Yield strength and ultimate strength of metals (in N/mm ² or MPa)
---	--

Design concepts

Partial safety factor concept (Eurocode, LRFD)

$$S_d \leq R_d$$

with:

$$S_d = \gamma_F \cdot S_k, \text{ and } R_d = \frac{R_k}{\gamma_{M,BT}}$$

S_d ... design action (internal forces and bending moment) acting on the stud
(N_{Sd} , V_{Sd} or M_{Sd})

S_k ... characteristic action acting on the stud (N_{Sk} , V_{Sk} or M_{Sk})

γ_F ... partial safety factor for actions

$$\gamma_F = 1.4 \text{ for general uses}$$

R_d ... design resistance of the stud (N_{Rd} , V_{Rd} or M_{Rd})

R_k ... characteristic resistance of the stud (N_{Rk} , V_{Rk} or M_{Rk})

$\gamma_{M,BT}$... partial safety factor of resistance for the new generation X-BT threaded studs

$$\gamma_{M,BT} = 2.0 \text{ in general}$$

$$\gamma_{M,BT} = 1.25 \text{ for bending of the stud itself}$$

Working load concept (ASD)

$$S_k \leq R_{rec}$$

with:

$$R_{rec} = \frac{R_k}{\gamma_{tot}} = \frac{R_k}{\gamma_{M,BT} \cdot \gamma_F} = \frac{R_k}{2.0 \cdot 1.4} = \frac{R_k}{2.8}$$

S_k ... characteristic action acting on the stud (N_{Sk} , V_{Sk} or M_{Sk}) =
Working load

Note on dead loads:

In many applications fasteners are stressed by the dead load of components. In that case the characteristic action (= working load) corresponds with the unfactored weight of the components supported by the X-BT threaded fasteners.

γ_{tot} ... total (global) safety factor

R_{rec} ... recommended service load values of the stud (N_{rec} , V_{rec} or M_{rec})

5.2 Static resistance of the new generation X-BT studs

5.2.1 Tensile load deformation behavior

Tension and shear tests with Hilti stud X-BT-GR M8/7 SN 8

Report 254/17, HTL-Rankweil (2017), Wechner W., 2017-12-04

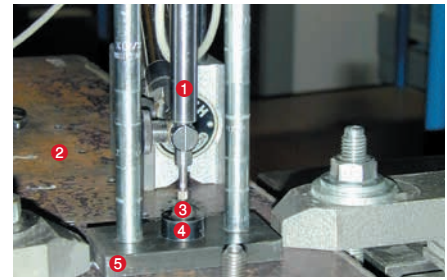
Evaluation report on new generation Hilti X-BT-GR, X-BT-MR and X-BT-ER threaded fasteners,

Hilti Report XE-18-12, Beck H., 2018-05-22

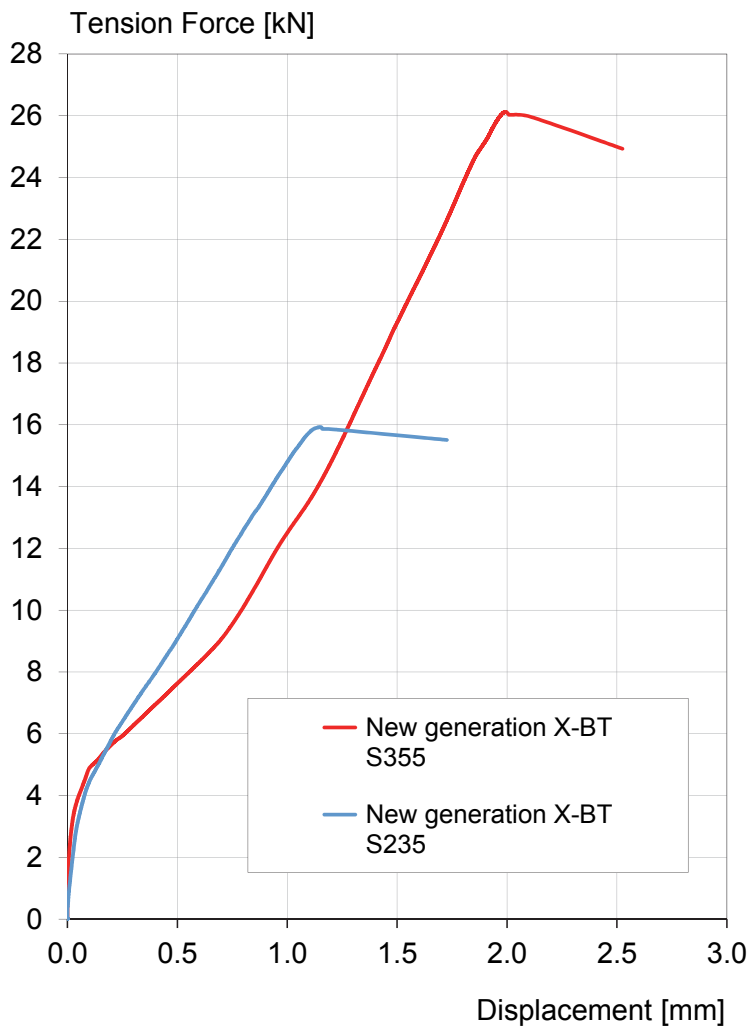
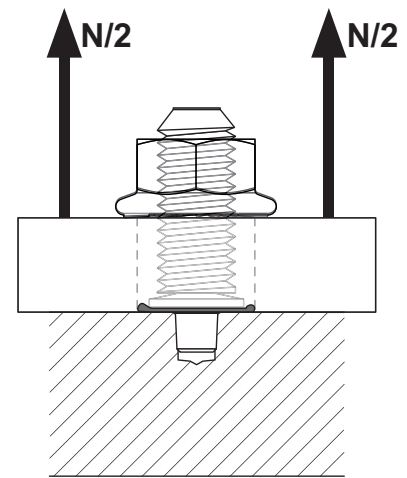
Base material steel:

8 mm with $f_u = 427 \text{ MPa}$ (S235) and 15 mm with $f_u = 634 \text{ MPa}$ (S355)

Number of fastenings per series: 10



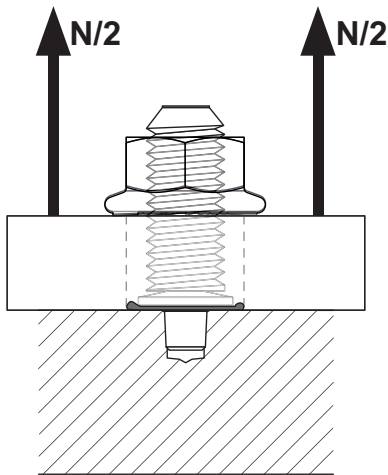
- ❶ Displacement sensor
- ❷ Base steel
- ❸ X-BT-M8/7 SN8
- ❹ Special nut, M10
- ❺ Loading plate



Conclusions

- Very high initial stiffness
- Sufficiently high deformations at ultimate load
- Ultimate pull-out loads increase with increasing base steel strength
- Load displacement characteristic is in well agreement with the observed friction welding anchoring mechanism

This summary is intended to be representative of the test(s) carried out. It is not intended to be a full and complete test report.



5.2.2 Tension pull-out strength

Evaluation report on new generation Hilti X-BT-GR, X-BT-MR and X-BT-ER threaded fasteners,

Hilti Report XE-18-12, Beck H., 2018-05-22

Base material steel: Thickness: 4, 6, 8, 12 and 15 mm, Grade: S235 up to S960

Coating thickness: $\geq 550 \mu\text{m}$

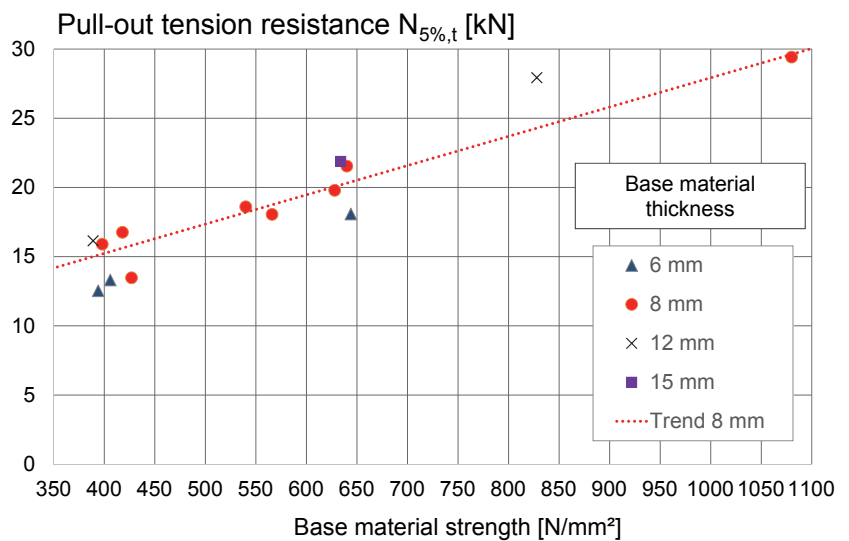
Number of fastenings per test: 10 or 20, in total 460 samples

Pull-out load depends on ultimate tensile strength of base material, relationship in uncoated steel:

Remark: Each data point represents the 5%-fractile $N_{5\%,t}$ of one test series

Conclusions

- Linear dependency of pull-out strength on the ultimate base steel strength.
- Even for low strength steel the 5% fractile of the pull-out resistance exceeds 10 kN.
- Little effect of base material thickness: Pull-out strength is independent on thickness for thickness ≥ 8 mm.
- Highest pull-out values achieved in high strength S960Q steel.

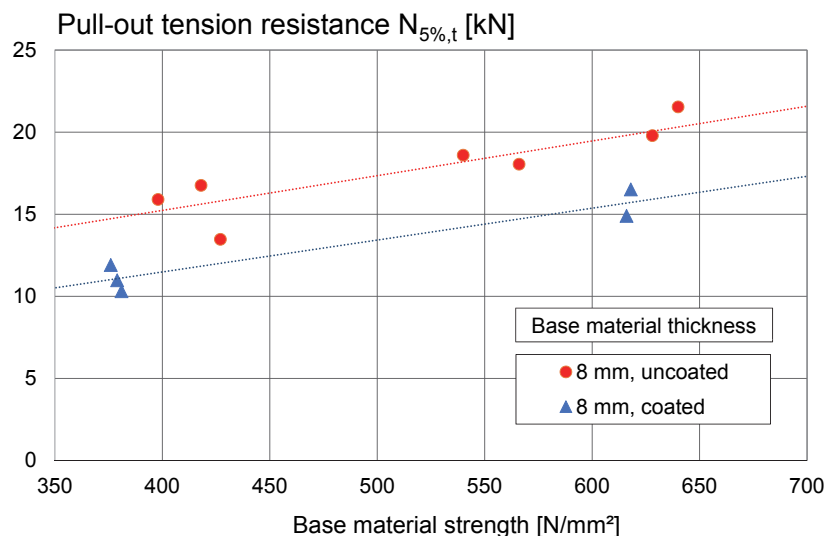


Effect of base material coating on pull-out strength:

Remark: Each data point represents the 5%-fractile $N_{5\%,t}$ of one test series

Conclusions

- Very reliable performance for coating thickness up to $500 \mu\text{m}$.
- Base material coating reduces pull-out strength due to reduced effective embedment in the base steel material.



This summary is intended to be representative of the test(s) carried out. It is not intended to be a full and complete test report.

5.2.3 Shear strength

Tension and shear tests with Hilti stud X-BT-GR M8/7 SN 8

Report 254/17, HTL-Rankweil (2017), Wechner W., 2017-12-04

Evaluation report on new generation Hilti X-BT-GR, X-BT-MR and X-BT-ER threaded fasteners,

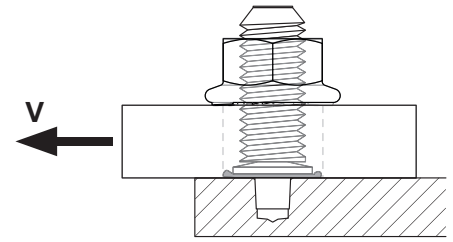
Hilti Report XE-18-12, Beck H., 2018-05-22

Base material steel: Thickness: 6, 8 and 15 mm, Grade: S235 and S355

Coated 8 mm steel: Coating thickness = 550 μm

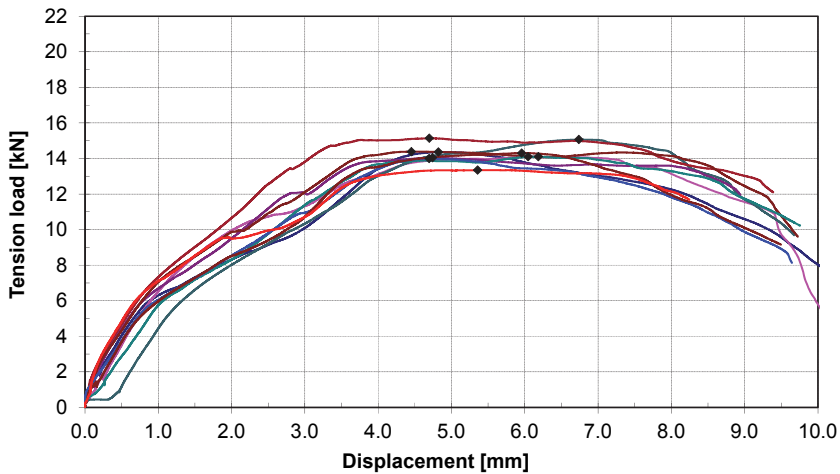
Number of fastenings per test: 10, in total 40 samples

Load introduction via the sealing washer



The graphs below show the individual load displacement curves of all 10 test samples per respective test series.

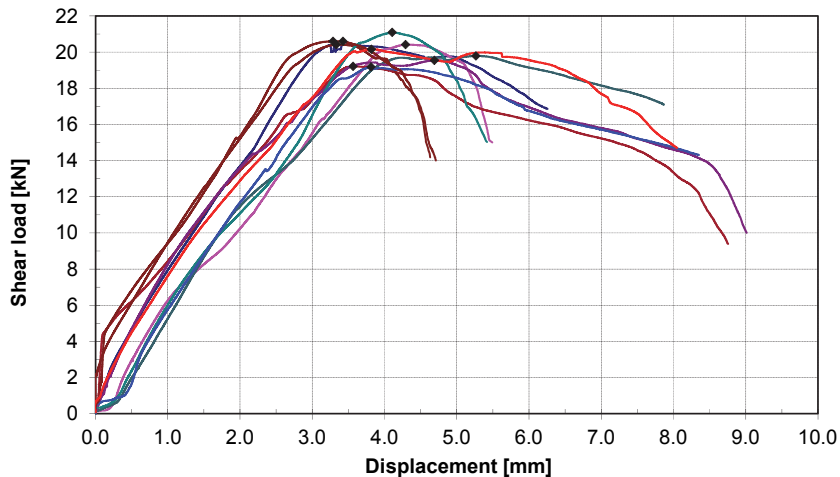
Load-displacement behavior: 8 mm, coated steel with $f_u = 376 \text{ MPa}$



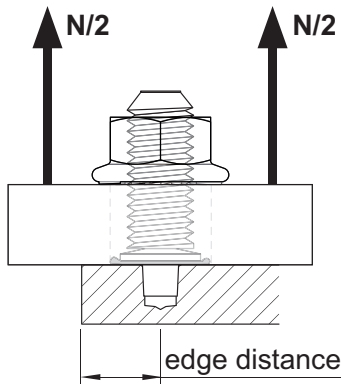
Conclusions

- High shear strength achieved both in low strength and high strength steel.
- Failure mode in general pull-out of stud after local bending deformation.
- Coating covered up to 500 μm coating thickness.
- High ductility allowing full utilization of group fastenings up to 4 studs per group (with a hole clearance of 2.5 mm).
 - Condition is shear load introduction via the sealing washer.
 - The hole clearance of 2.5 mm corresponds with a hole diameter of 14 mm in the fastened material.

Load-displacement behavior: 15 mm, uncoated steel with $f_u = 632 \text{ MPa}$



This summary is intended to be representative of the test(s) carried out. It is not intended to be a full and complete test report.



5.2.4 Effect of edge distance and spacing on pull-out strength

Evaluation report on new generation Hilti X-BT-GR, X-BT-MR and X-BT-ER threaded fasteners,

Hilti Report XE-18-12, Beck H., 2018-05-22

Edge distance

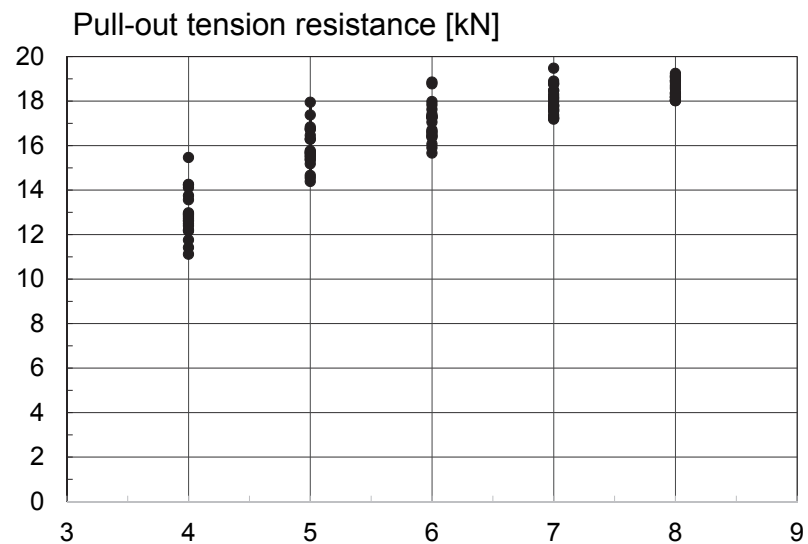
Base material steel: Thickness 20 mm, Grade S235 ($f_u = 435$ MPa), uncoated

Number of fastenings per edge distance: 20

Edge distances tested: 4, 5, 6, 7 and 8 mm

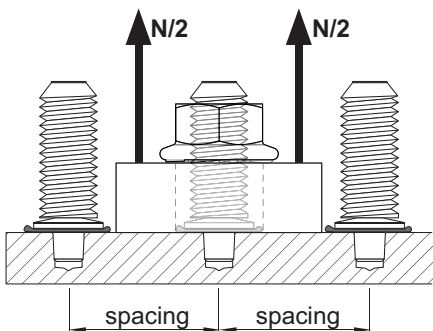
Test concept

- 1) Drive new generation X-BT fasteners at various edge distances
- 2) Pull out of all fasteners
- 3) Compare ultimate pull-out loads for the various fastenings



Conclusions

- Very robust behavior observed even at very close edge distance.
- Minimum edge distance of 6 mm clearly confirmed.



Fastener spacing

- Minimum fastener spacing of 15 mm is determined by the dimensions of the base plate of the DX 351 BT or DX 351 BTG tool.
- An increased spacing beyond 15 mm does not increase ultimate pull-out resistance (unchanged compared with the previous generation of X-BT threaded studs, see test data in the Hilti X-BT Threaded Fastener Specification, July 2015)
- A minimum fastener spacing of 15 mm is adequate to avoid reduction in recommended load.

This summary is intended to be representative of the test(s) carried out. It is not intended to be a full and complete test report.

5.2.5 Holding mechanisms of X-BT threaded studs

Description of the holding mechanism

- The drill hole diameter of the pilot hole is smaller than the conical blunt tip of the X-BT threaded fastener. When driving the X-BT stud into steel, high temperatures develop along the contact surface between the tip of the X-BT fastener and the carbon steel base material. This process leads to predominant fusion of the stud with the base material due to friction welding.
- This mechanism is confirmed by metallurgical examination of the cross section as well as by visual investigation of pulled-out fasteners. Furthermore, the achieved tension pull-out resistance suggests that shear failure of the base material along the contact area with the tip controls the ultimate resistance.
- Due to this anchorage mechanism, the drilled hole below the tip of the X-BT threaded stud remains sealed.

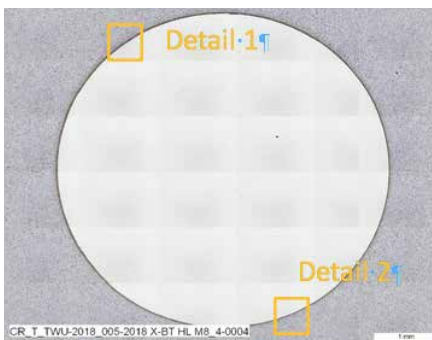
View of pulled-out fastener

Base material attached to the pulled threaded fastener is clearly visible.



View of cross section 3 mm below top surface of base material

Metallurgical investigations confirm fusion due to friction welding along the entire perimeter.



Detail 1, etched with 2 % Nital



Detail 2, etched with 2 % Nital

This summary is intended to be representative of the test(s) carried out. It is not intended to be a full and complete test report.

5.3 Corrosion resistance

5.3.1 X-BT threaded stud corrosion information

The new generation X-BT threaded fasteners maintain at least the same durability as the previous generation of X-BT threaded fasteners.

- Comprehensive investigations on the corrosion resistance of the previous generation of X-BT threaded fasteners were performed to assess the durability of the fastener in marine environment (test data see Hilti X-BT Threaded Fastener Specification, July 2015).
- The complete body of the new generation X-BT threaded fasteners is now made from ferritic-austenitic corrosion resistant duplex steel 1.4462. This material is known and recognized for reliable uses in marine environment. It has a Pitting Resistant Equivalent (PRE) of ≥ 34 (for comparison: A4 or 316 austenitic steel have a PRE of about 25).
- For the duplex steel 1.4462 the breakdown potential of the fasteners in artificial seawater – a very corrosive medium even for corrosion resistant steel – amounts to more than $1200 \text{ mV}_{\text{SHE}}$. For comparison the pitting potential in artificial seawater of A4 or 316 austenitic steel amounts to about $800 \text{ mV}_{\text{SHE}}$.
- The reliable and proven concept of sealing the entrance location of the X-BT threaded stud with a sealing washer remained unchanged with the new generation threaded studs.
- Test samples of coated base material exposed to salt spray testing show no evidence of corrosion. The pullout resistance of the threaded fasteners is not affected by the exposure to the atmosphere.

Observations and examination from salt spray testing

After 480 hours of salt spray testing, the bottom side of the 8 mm [5/16"] steel plate was examined. No evidence of damage or corrosion could be found.

Drilled holes after 480 hours of salt spray test and after pull-out of the X-BT fasteners. These holes appear clean and no evidence of corrosion is visible.



Conclusions from the tests

- Tests confirm durability of the new generation X-BT threaded fasteners to be at least equivalent with the previous generation of X-BT threaded studs (described in Hilti X-BT Threaded Fastener Specification, July 2015)
- After salt spray tests no corrosion was found in the drilled holes. This is strong evidence that the sealing washer provides an effective seal.
- After salt spray tests, there was no evidence of corrosion on the bottom side of the steel plate. This shows that drilling the hole and driving the fastener does not cause damage on the bottom side.
- Corrosion resistant material 1.4462 covers all A4 or AISI grade 316 uses.

This summary is intended to be representative of the test(s) carried out. It is not intended to be a full and complete test report.

5.3.2 Contact corrosion – X-BT stainless steel stud in carbon steel

Test Report:

Corrosion behavior of stainless steel DX fasteners in carbon steel;

G. Felder and M. Siemers, Schaan, September 2005

When it comes to contact corrosion, the new generation X-BT threaded fasteners have same performance as the previous generation.

Therefore, the following section taken from the “X-BT Threaded Fastener Specification”, July 2015, fully applies for the new generation X-BT threaded fasteners.

General comments

Two materials of different resistance/polarity exposed to the same media, in direct electrical contact, lead to accelerated corrosion of an electrochemically “less noble” material in contact with a “noble” material. The material loss of the noble partner is reduced, the loss of surface area of the less noble partner is increased. Prerequisite for this form of corrosion is an electrically conductive connection between these two materials.

Whether contact corrosion occurs depends also on the **surface area ratio**.

If the surface of the less “noble” material (1) is greater than that of the more “noble” material (2), it will act as a very small cathode and the current density on the “large anodic” less noble material will be very small. Further, this also implies a very low rate of corrosion of the “less noble” material due to electrochemical effects.

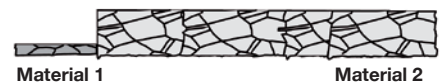
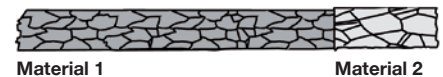
However, if the surface of the less “noble” material (1) is smaller than that of the more “noble” material (2), the rate of corrosion of the “less noble” material will be very high.

Hilti X-BT in carbon steel

Where stainless steels are concerned, contact corrosion is not a matter of concern. Stainless steels are higher in the galvanic series, i.e. more noble than most generally used materials such as aluminium, zinc and steel. Stainless steel in contact with these materials thus gains cathodic protection. Contact therefore generally has a favorable effect on the corrosion properties of stainless steels.

Due to the electrochemical effects as described above, the “noble” stainless steel fastener induces a very low rate of corrosion of the “less noble” base material and fastened material, or possibly no corrosion at all. This behavior has also been confirmed in a number of salt spray tests and in long-term tests with exposure to sea water in the tidal zone on an island in the North Sea.

In all of these tests, no corrosion occurred. The condition of a specimen after 10 years of sea water tests is shown in the photo on the left. No evidence of corrosion can be found at the anchoring zone of the X-BT fastener. The seal has remained fully functional, no electrolyte is present and contact corrosion is not an issue.



Steel base material after 10 years of exposure to sea water and pull-out of the X-BT fastener. The hole appears clean and no evidence of corrosion is visible.



- 8 specimens in an atmospheric test rig in accordance with ISO 8565
- 16 specimens in a sea water testing rig, wave zone and tide zone, in accordance with ISO 11306



Marine atmosphere test rig with X-BT test specimens installed.



See water test rig with test specimens installed (X-BT with and without X-FCM grating discs).



5.3.3 Corrosion data from field tests at Helgoland Island (North Sea)

Test reports:

Expert assessment: Investigation of the corrosion resistance of Hilti X-BT fasteners in marine atmospheres and in sea water,

9004742000 G/Bf; MPA, University of Stuttgart; Feb 3, 2014

Expert opinion: New Generation X-BT,

9034407000 /Bf; MPA, University of Stuttgart; Jan. 8, 2018

Due to the design of the new generation X-BT threaded fasteners, they offer at least comparable corrosion resistance as the previous generation of X-BT threaded fasteners.

Therefore, the following section – summarizing the field tests at Helgoland Island and taken from the “X-BT Threaded Fastener Specification”, July 2015 – fully applies for the new generation X-BT threaded fasteners:

Test material

Base material	S235 steel ($f_u = 439$ MPa), 8 mm thick
Number of specimens	24 steel plates, each with 18 X-BT studs

Test procedure

The test specimens were installed in May 2003 and samples taken periodically from each zone for assessment in June 2004, June 2005, May 2008 and April 2013.

Microscopic and metallurgical investigations to assess corrosion were carried out by MPA, University of Stuttgart. The tensile resistance tests were carried out by Hilti under supervision of the MPA.

Test results

Test specimens after 10 years of exposure to sea water in the tidal zone of the North Sea. No evidence of corrosion is visible on the X-BT studs and X-FCM discs. Only slight discoloration due to deposits can be observed on the X-FCM discs.

Conclusions

- After 10 years of exposure to sea water, no obvious signs of corrosion were found on the X-BT fasteners. After 10 years of exposure to sea water, no relevant signs of corrosion were found on the X-FCM fasteners.
- After 10 years of exposure to sea water, no corrosion was found in the drilled holes. This is strong evidence that the sealing washer provides an effective seal.
- Ultimate pull-out strength of the fasteners was not affected by the field tests. The pull-out load achieved in monitoring tests carried out in June 2003 was 8.6 kN, and in 2013 it was 10.3 kN (Note: These values refer to the previous generation of X-BT threaded fasteners).

This summary is intended to be representative of the test(s) carried out. It is not intended to be a full and complete test report.

Based on the long-term tests carried out by the MPA as described above as well as the investigation of the new generation X-BT threaded studs, the University of Stuttgart (Expert Opinion 9034407000 / Bf; MPA, University of Stuttgart; Jan 8, 2018) came to the following conclusion:

It can thus be assumed that the new generation Hilti X-BT fasteners made from stainless steel are of at least comparable resistance under atmospheric corrosion conditions to the current X-BT studs. In atmospheres containing chloride ions, i.e. in atmospheres of the corrosivity categories C4 or C5 (C5-M), they can be assumed to have a life expectancy, from a corrosion point of view, of more than 40 years.



Steel base material after 10 years of exposure to sea water and pull-out of the X-BT fastener. The hole appears clean and no evidence of corrosion is visible.

5.4 Effect of X-BT threaded stud fastenings on steel base material

Evaluation report on new generation Hilti X-BT-GR, X-BT-MR and X-BT-ER threaded fasteners,

Hilti Report XE-18-12, Beck H., 2018-05-22

Tensile tests for determination of mechanical properties: Flat-sheet specimens made of steel S235JR and P355NL1 without fastener, with one fastener of type X-BT-GR M8/7 SN8, with two fasteners of type X-BT-GR M8/7 SN8 and pulled out fastener respectively,

EMPA, Test report No 5214017148/e (2018): Swiss Federal Laboratories for Materials Testing and Research (EMPA), Dübendorf, Switzerland, January 16th 2018

Constant amplitude fatigue tests: Flat-sheet fatigue specimens made of steel S235 JR+N with correctly installed fasteners of the new generation type X-BT-GR M8/7 SN8, removed fasteners and drill hole respectively,

EMPA, Test report No 5214017145/3e (2018): Constant amplitude fatigue tests: Swiss Federal Laboratories for Materials Testing and Research (EMPA), Dübendorf, Switzerland, January 15th 2018

Fatigue classification of the constructional detail „Structural steel base material with the Hilti power-actuated threaded fasteners X-BT-GR and X-BT-MR”,

Kuhlmann, U., Günther, H.P. (2018): Report, University of Stuttgart, Institute for Construction and Design, 19.5.2018, Nr. 2018-13X

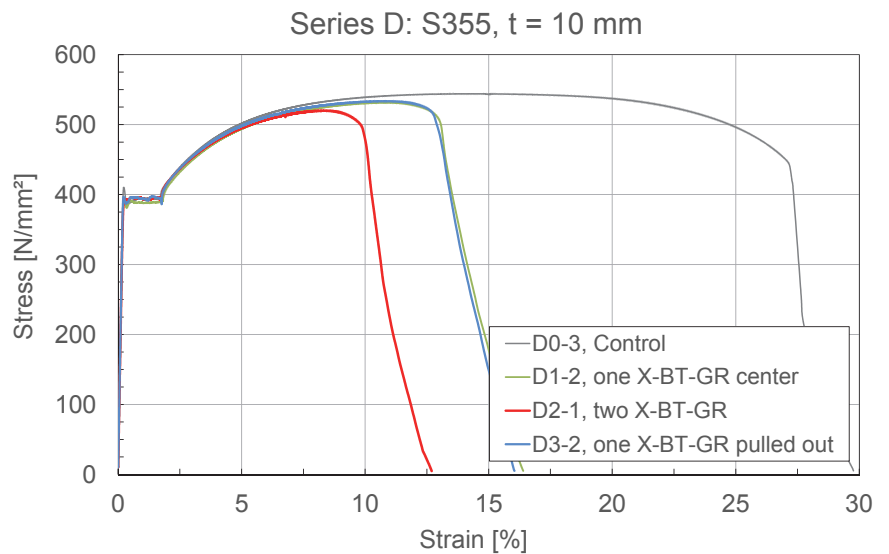
Base material (static tests):	Steel 8 and 10 mm, grade S235 and S355
Base material (fatigue tests):	Steel: 8, 20 and 40 mm, grade S235 and S960
Number of tests:	48 static tensile and 58 fatigue tests



5.4.1 Net section efficiency

Load-deformation behavior of steel with X-BT fasteners

Evaluated in tensile tests performed with coupons with X-BT fasteners, XE-18-12



Conclusions

- Very high net section efficiencies – as observed with Hilti DX powder-actuated fasteners as well as with the previous generation of X-BT fasteners – also developed for plates with new generation X-BT threaded fasteners.
- Generally, the presence of an X-BT fastener need not be taken into account in the design of tensile members made of structural steel.
- In case of exceptionally high fastener concentrations (net area < 92 % of gross area according to AISC provisions) and if strict code compliance is required, application of the design provisions of AISC-LRFD or Eurocode 3 (EN 1993-1-1) for drilled holes leads to conservative designs.

This summary is intended to be representative of the test(s) carried out. It is not intended to be a full and complete test report.

5.4.2 Fatigue classification in compliance with Eurocode 3 (EN 1993-1-9) "Structural steel base material with Hilti power-actuated fastener X-BT-GR, X-BT-MR and X-BT-ER"

Hilti ran already a comprehensive fatigue test program for the previous generation of X-BT threaded fasteners to classify the constructional detail "Structural steel base material with the Hilti powder-actuated fastener X-BT" in compliance with the Eurocode 3 (EN 1993-1-9). Results are summarized in the "X-BT Threaded Fastener Specification", July 2015.

Hilti complemented those investigations with a supplemental comprehensive fatigue test program with steel plates with installed new generation X-BT threaded fasteners. Those tests were again performed at EMPA (Swiss Federal Laboratories for Materials Testing and Research) in Dübendorf, Switzerland. The respective evaluation of the tests results was again made by Prof. U. Kuhlmann and Prof. H.P. Günther from the University of Stuttgart (Report No. 2018-13X). Table 1 shows the results of the detail classification according Eurocode 3, EN 1993-1-9.

Detail category	Constructional detail	Description	Requirements
100* m = 5		<p>New generation Hilti X-BT-GR, X-BT-MR and X-BT-ER power-actuated fasteners with pre-drilled hole in structural steel base material.</p> <p>Imperfect fastener installations as e.g. pulled-out fasteners or pre-drilled holes without fasteners are covered.</p>	<p>$\Delta\sigma$ to be calculated by the gross cross-section.</p> <p>Installation, static loading and spacing of fasteners only in accordance with the requirements given in [1].</p> <p>Plate thickness $t \geq 8$ mm</p> <p>Edge distance ≥ 15 mm</p> <p>When using a fatigue assessment based on a linear damage calculation a mixture of both detail categories is not allowed.</p>
<p>* Alternatively to the propose detail category 100 with m = 5, detail category 90 with m = 3 can be use for $\Delta\sigma \leq 200$ N/mm². Structural steel grades S235 up S960 to EN 10025-2, EN 10025-3, EN 10025-4, EN 10025-6 and EN 10225 are covered. These grades include thermo-mechanically rolled fine grain steels (e.g. S460M) as well as structural high strength steel grades S690 up to S960.</p> <p>[1] Hilti (2018): New Generation Hilti X-BT-GR and X-BT-MR Threaded Fastener Specification. Edition 2018.</p>			

Table 1. Recommendation of fatigue detail category according to EN 1993-1-9:2005, classification by University of Stuttgart, Prof. Kuhlmann and Prof. Günther, Report No. 2018-13X.

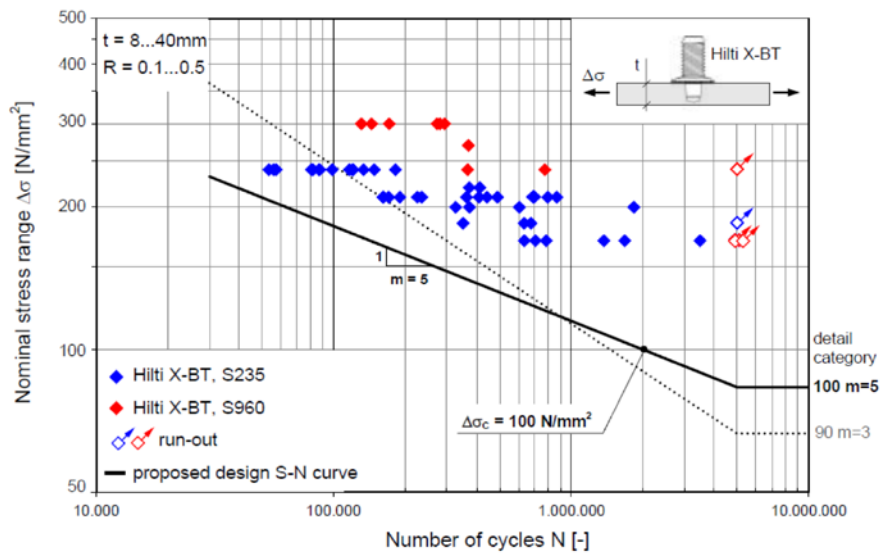
Conclusions

- The test results confirm the good-natured behavior known from standard DX powder-actuated fasteners as well as from the previous generation of X-BT threaded fasteners.
- The Eurocode 3 detail category 100 with the slope m = 5 was clearly confirmed for the new generation X-BT threaded studs. This category is equivalent with the classification of the previous generation of X-BT threaded studs.
- The Eurocode 3 detail category 90 with the slope m = 3 can be applied provided the stress ranges $\Delta\sigma \leq 200$ N/mm².
- For typical uses of the X-BT fasteners where fatigue design is essential (e.g. for fastening of equipment in steel towers of wind power plants), the category 100 with m = 5 is in general to be preferred due to load protocols with typically high number of load cycles.

This summary is intended to be representative of the test(s) carried out. It is not intended to be a full and complete test report.



Survey of fatigue test results



Mathematic description of category 100, $m = 5$

$$\log N = \log a - m \cdot \log S$$

with:

$\log N$... logarithm to base 10 of corresponding cycles of failure N

$\log a$... intercept on the $\log N$ axis

$\log a = 16.3$ and $m = 5$

m ... negative slope of S-N curve being linear on a log-log basis

$\log S$... logarithm to base 10 of stress range S ($S = \Delta\sigma$)

This summary is intended to be representative of the test(s) carried out. It is not intended to be a full and complete test report.

5.4.3 Approved fastigue categories by DNV-GL (Det Norske Veritas - Germanischer Lloyd), LR (Lloyd's Register), ABS (American Bureau of Shipping) and BV (Bureau Veritas)

Towers for wind turbines, offshore structures or crane constructions often are approved by classification societies like DNV-GL, LR, ABS or BV. Those classification societies also approved the fatigue category for the constructional detail "Structural steel base material with new generation Hilti X-BT-GR, X-BT-MR and X-BT-ER poweractuated fasteners", see Table 2.

Classification Society	Hilti Type Approval Certificate	Fatigue standard	Detail category
DNV-GL	TAS00001SV	DNVGL-RP-C203	"X-BT" (100, m = 5)
		EC 3, EN 1993-1-9	100, m = 5
LR	19/0003	EC 3, EN 1993-1-9	100, m = 5
ABS	18-HS1755518-PDA	ABS Offshore Guide	F
		EC 3, EN 1993-1-9	100, m = 5
BV	54054	EC 3, EN 1993-1-9	100, m = 5

Applicable for base material thickness $t \geq 8$ mm and for edge distance ≥ 15 mm

Table 2. Approved fatigue detail categories

Notes on DNV-GL Type Approval:

In addition to the fatigue category 100, m = 5 per EN 1993-1-9, the fatigue category "X-BT" is applicable in connection with DNVGL-RP-C203 (Recommended Practice: Fa-tigue design of offshore steel structures, April 2016). The category "X-BT" represents the product specific fatigue category described in the format of DNVGL-RP-C203 (Table 2-1, S-N curves in air).

The parameters of category "X-BT" are:

- for $N \leq 10^7$ cycles: $m_1 = 5.0$, $\log a_1 = 16.300$
- for $N > 10^7$ cycles: $m_2 = 5.0$, $\log a_2 = 16.300$
- Fatigue limit at 10^7 cycles: 72.4 N/mm²
- Thickness exponent $k = 0$

Alternatively to the category "X-BT", the detail category D per DNVGL-RP-C203 may be used for $\Delta\sigma \leq 200$ N/mm².

Structural steel grades: S235 up to S960Q according to EN 10025-2, EN 10025-3, EN 10025-4, EN 10025-6 and EN 10225

Notes on ABS Type Approval:

Class F in air condition (A) per ABS Guide for Fatigue Assessment of Offshore Structures, American Bureau of Shipping, April 2003, updated 2018, applicable for structural steel grades with a nominal yield strength ranging from 235 to 960 N/mm². Classification 100, m = 5 per EN 1993-1-9 applicable for structural steel grades S235 to S460 according to EN 10025-2, EN 10025-3, EN 10025-4 and EN 10225 and for grades S690Q to S960Q according to 10025-6.

Notes on LR Type Approval:

Classification 100, m = 5 per EN 1993-1-9 applicable for structural steel grades S235 to S460 according to EN 10025-2, EN 10025-3, EN 10025-4 and EN 10225 and for grades S690Q to S960Q according to 10025-6.
number of load cycles.

Notes on BV Type Approval:

Classification 100, m = 5 per EN 1993-1-9 applicable for structural steel grades S235 to S460 according to EN 10025-2, EN 10025-3, EN 10025-4 and EN 10225 and for grades S690Q to S960Q according to 10025-6.

Fatigue verification of structural members in ship structures has to be made with the corresponding Bureau Veritas Rules and is subject to specific consideration of Bureau Veritas.

This summary is intended to be representative of the test(s) carried out. It is not intended to be a full and complete test report.

5.5 Technical data for X-BT fastenings made to cast iron with spheroidal graphite

5.5.1 Cast iron specification

Components made from cast iron with spheroidal graphite are typically used in the nacelle of wind towers. The preferred grade is EN-GJS-400-18-LT according to EN 1563 with a minimum ultimate strength of 400 N/mm², a minimum fracture strain A of 18 % and with impact toughness properties suitable for use in cold temperatures. The use of cast iron with spheroidal graphite allows economical production of complex machinery parts combined with ductile material behavior.

The presence of spherical graphite is required to allow the casting process. Figure 1 shows a representative example of a micro section of cast iron EN-GJS-400-18-LT. The distribution of the spheroidal graphite in the ferritic matrix is clearly visible.

The cast iron needs to meet the following specification given in Table 3. The listed carbon content and microstructure is typical for EN-GJS-400-18-LT used in the nacelle of wind towers.

Subject	Requirements
Cast iron	Spheroidal graphite cast iron according to EN 1563
Strength class	EN-GJS-400 to EN-GJS-600 according to EN 1563
Chemical analysis and amount of carbon	3.3 - 4.0 mass percentage
Microstructure	Form IV to VI (spherical) according to EN ISO 945-1:2010 Minimum size 7 according to Figure 4 of EN ISO 945-1:2010
Material thickness	$t_{II} \geq 20$ mm

Table 3. Requirements of spheroidal graphite cast iron base material

5.5.2 Grounding and bonding restrictions

No corresponding experimental investigations have been made so far. Therefore, the use of X-BT-ER fasteners for grounding and bonding application is not covered, in case the fasteners are driven to cast iron components.

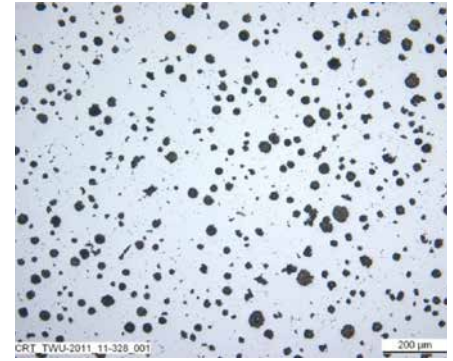


Figure 1. Micro section of cast iron EN-GJS-400-18LT: Spheroidal graphite embedded in ferritic matrix

5.5.3 Performance review

The new generation X-BT threaded fasteners achieves double the performance compared with previous generation of X-BT threaded fasteners.

- Comprehensive experimental investigations with the previous generation of X-BT threaded fasteners were performed to assess their resistance in cast iron (test data see Hilti X-BT Threaded Fastener Specification, July 2015).
- New tension tests clearly confirmed the suitability of the new generation X-BT threaded studs on cast iron. Due to the improved point design the resistances of the new generation X-BT threaded studs are double as high than the values of the previous generation of X-BT threaded studs.

An extract of the fundamental behavior – taken from the “X-BT Threaded Fastener Specification”, July 2015, is repeated as follows:

The scope of the test program performed with the previous generation of X-BT studs included the following experimental investigations (summary and assessment in [1]):

- Static pullout tests
- Static shear and bending tests
- Tension fatigue tests
- Tests to cover the effect of the edge distance
- Tests to cover the effect of the cast iron surface

Compared with the performance of the previous generation X-BT fasteners in unalloyed structural steel, the recommended load values in cast iron were smaller due to the presence of graphite in the cast iron. As with unalloyed structural steel, reliable anchorage of the X-BT fastener developed also in case of cast iron base material. The anchorage is also caused by predominantly friction welding between the fastener shank and the ferritic or perlitic matrix of the cast iron. However, the presence of the graphite reduces the effective contact area, which explains the reduction of the pullout strength.

Furthermore, the recommended loads implicitly cover effects of dynamic and variable loading on the fastener. This statement is based on the results of tension fatigue tests, which were performed to investigate the robustness of the anchorage of X-BT fasteners in cast iron, see Figure 2 and 3.

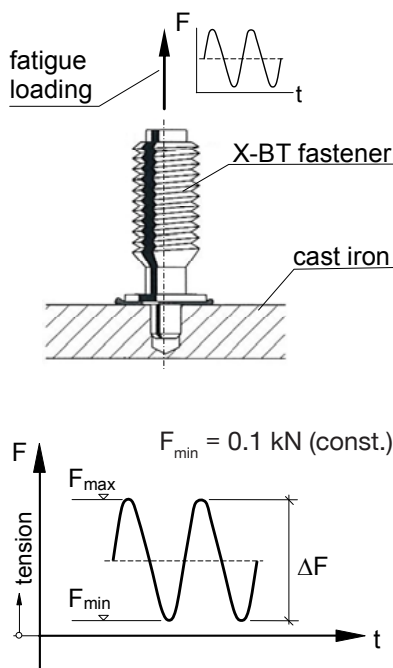


Figure 2. Principle sketch of cyclic tension tests



Figure 3. Servo-hydraulic test setup for tension fatigue tests

This summary is intended to be representative of the test(s) carried out. It is not intended to be a full and complete test report.

Conclusions from the cyclic tension tests:

- The anchorage of the X-BT does not work loose. In none of the tests pull-out of the fastener from the cast iron was the controlling mode of failure.
- Failure was controlled by fatigue fracture of the stainless stud material. The fractures occurred at upper loads significantly beyond the recommended tension load (0.5 kN for the previous generation, 1.0 kN for new generation X-BT fastener).
- For final verification and with respect to the reported design life of wind towers, two fatigue tests were performed with an upper load of 1.0 kN and a target number of 200 million load cycles.
- Both “long run” samples passed the test without any damage, neither lead to fracture of the stud material nor to failure of the anchorage. Residual static pullout tests of these two samples (from the previous generation of X-BT studs) resulted in a pullout strength beyond 5 kN.
- These test results clearly verified reliable X-BT fastenings to cast iron EN-GJS-400-18LT used in the nacelle of wind towers.

Figure 4 shows a graph of the fatigue test results performed with the X-BT fasteners. The load-level of the runouts (at 10 Mio load cycles) is by far beyond the recommended working load of 0.5 kN of the previous and 1.0 kN of the new generation X-BT threaded fastener, especially see the two run-outs at 200 million load cycles with an upper load of 1.0 kN.

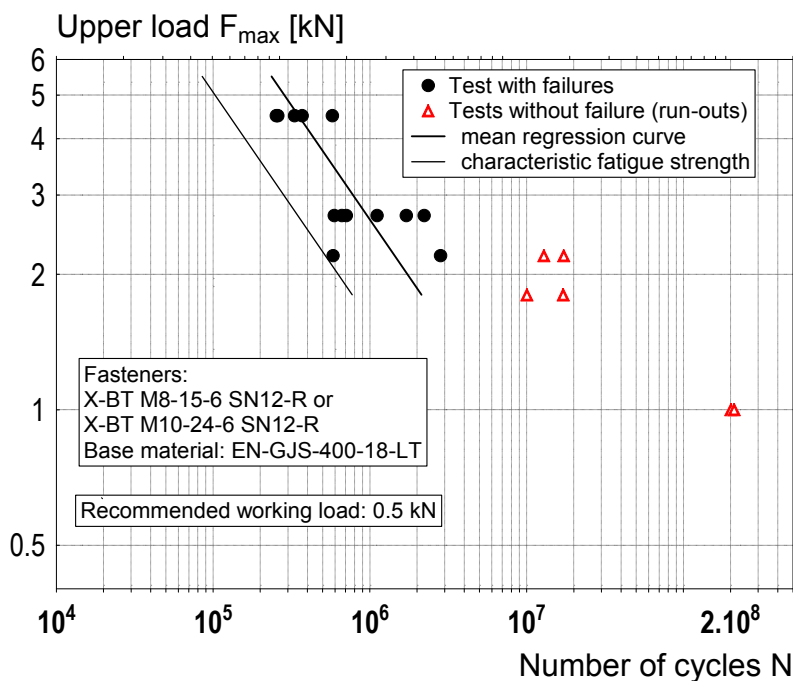
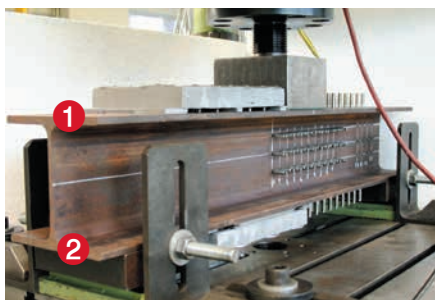


Figure 4. Results of cyclic tension tests

Literature:

- [1] Kuhlmann, U., Günther, H-P. (2011): Hilti powder-actuated fastener X-BT in combination with the Hilti fastening tools DX 351 BT/BTG for the use in cast iron base material according to EN 1563, Evaluation Report, Institut für Konstruktion und Entwurf, Stahl- Holz- und Verbundbau, University of Stuttgart, Report Nr. 2011-24X, Oct. 11, 2011.



1 Compression flange
2 Tension flange



3 Markings to measure disc rotation

5.6 Vibration effects on X-BT threaded stud fastenings

The anchorage of the new generation X-BT threaded fasteners is robust related to dynamic base material stress (vibration) as well as related to dynamic loading of the stud itself.

Due to the similar friction welding anchorage mechanism, the general conclusions drawn from the base material vibration tests performed with the previous generation of X-BT threaded fasteners apply also for the new generation X-BT threaded fasteners.

Therefore, those tests performed with the previous generation of X-BT fasteners are summarized below. The sections are taken from the “X-BT Threaded Fastener Specification”, July 2015:

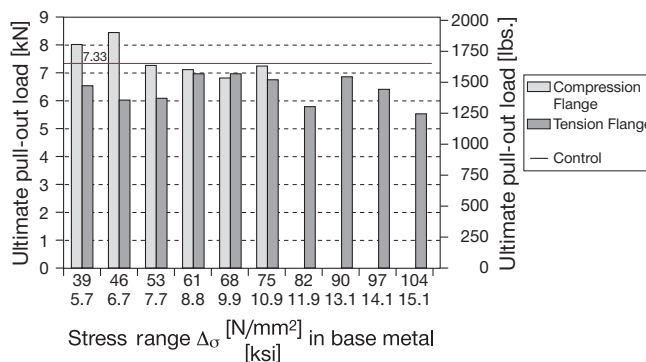
Experimental investigations on the effect of base metal vibrations on the ultimate pull-out strength

Report No. XE-02-09, Beck H., 19 June 2002

Base material	Steel, S235
Beam section	HE-A section, 9 mm flange, 6 mm web
Test procedure:	Beam loaded in the center $F_{max} = 155 \text{ kN}$, $F_{min} = 33 \text{ kN}$ Frequency = 6 Hz Number of cycles = 2 Million
Number of fastenings:	210 X-BT fasteners, some with X-FCM-R grating disks

Tension pull-out loads of X-BT fasteners before and after cyclic loading of the steel beam

X-BT fasteners in area without grating



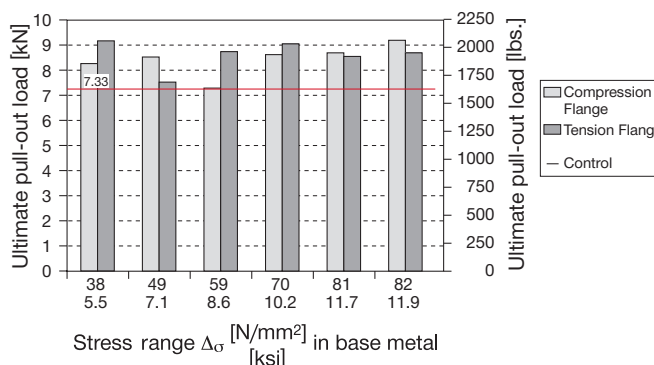
Notes:

- 7.33 kN = Ultimate pull-out load of the sample before stress was applied (control).
- No measurements taken on the compression flange in the high stress area due to position of the press.

Conclusions

- Cyclic loading applied to steel beams, which causes vibration on the fastener, has only a negligible effect on the ultimate pull-out of X-BT threaded studs
- Cyclic loading applied to steel beams, which causes vibration on the fastener, does not result in loosening of grating X-FCM-R grating disks

X-BT fasteners in area with grating

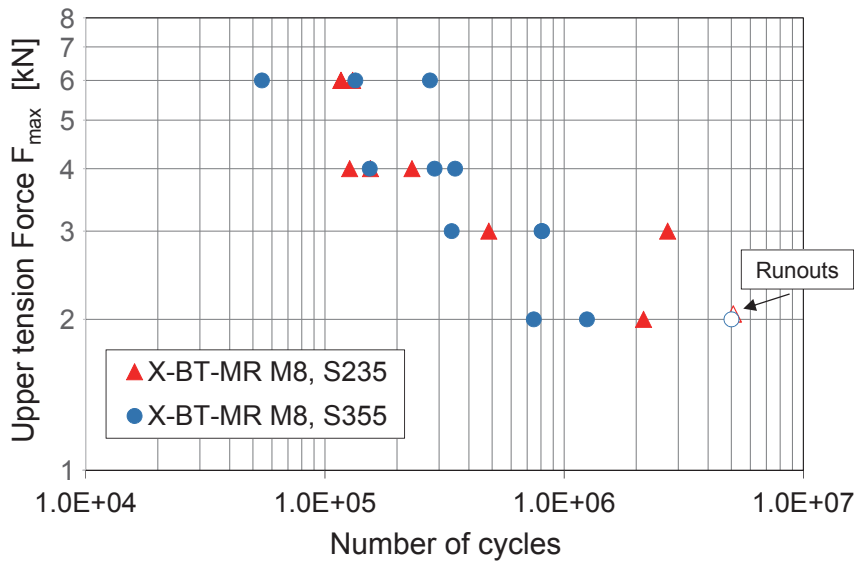
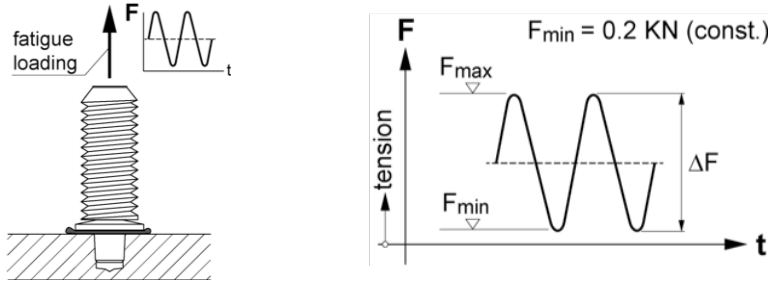


This summary is intended to be representative of the test(s) carried out. It is not intended to be a full and complete test report.

Dynamic tension loading on the new generation X-BT threaded fastener demonstrates excellent robustness of anchorage.

Evaluation report on new generation Hilti X-BT-GR, X-BT-MR and X-BT-ER threaded fasteners,

Hilti Report XE-18-12, Beck H., 2018-05-22



Conclusions

- The anchorage does not work loose due to dynamic loading. Fatigue fracture of the stud material itself controls the fatigue life of the connection.
- Quasi-static design applying the recommended tension load values is conservatively and clearly covered.

Note

In case fatigue design of the new generation X-BT is required, inquire at Hilti.

This summary is intended to be representative of the test(s) carried out. It is not intended to be a full and complete test report.

5.7 Temperature resistance of X-BT threaded stud fastenings

Evaluation report on new generation Hilti X-BT-GR, X-BT-MR and X-BT-ER threaded fasteners,

Hilti Report XE-18-12, Beck H., 2018-05-22

The temperature resistance of the Hilti X-BT fastening system is affected by

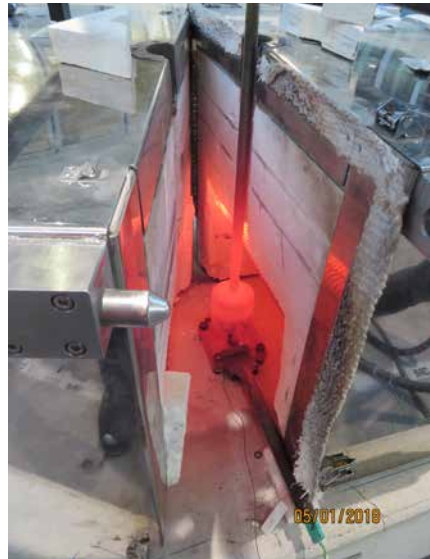
- the temperature resistance of the stud itself
- the resistance of the X-BT stud anchorage in steel base material
- the temperature resistance of the SN sealing washer
- the effect of temperature on the corrosion resistance of the stud

Temperature resistance of the new X-BT stud and its anchorage in carbon steel

Base material steel: Thickness 10 mm, Grade S235 (Rm = 367 MPa)

Tested temperature: 20 °C and elevated temperatures 200 °C, 400 °C, 600 °C (10 samples per temperature) and -50 °C with 5 samples

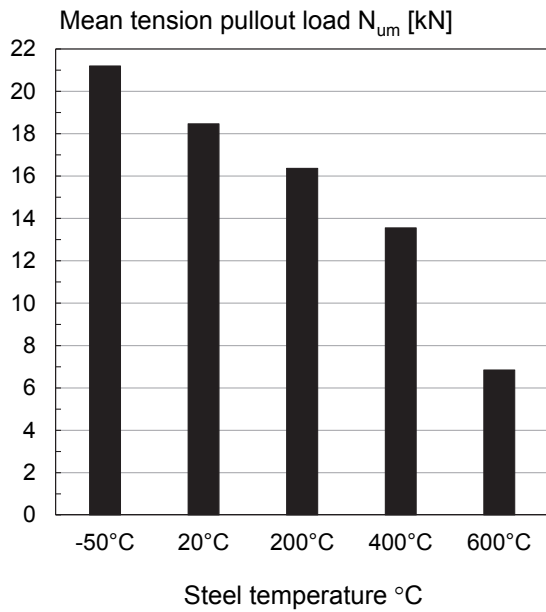
Pull-out test configuration



The chamber is heated as long, till the test temperature of the steel base material is reached. The right photo shows the temperature sensor ("black wire") which is fixed in the base material in a small bore hole of 2 mm diameter close to the X-BT threaded fastener. If the target temperature in the base steel is reached, the tension pull-out test is performed (with closed chamber). The photos show the opened chamber after the tension test was executed.

The samples for the cold temperature tests were prepared in a separate cooling chamber.

Results



Conclusions

- Pull-out of the stud from the carbon steel was the controlling mode in all cases. The reduction of the tension pull-out resistance follows approximately the effect of temperature on the strength of construction steel. This observation is in well agreement with the friction welding anchorage mechanism.
- In all test series the scatter is very small with a maximum COV of 6.2% at 600 °C.
- If the fastener is used on fire protected steel structures (with steel temperature typically less than 600 °C in case of a fire), the full utilization of the recommended service loads will often be possible. The respective specific safety margins in case of a fire need to be observed.

Statements on long-term temperature:

The same provisions as for the previous generation of X-BT threaded fasteners remain valid, the recommended service temperature amounts between -40 °C to +100 °C. Those limits are determined by the sealing function of the rubber material of the sealing washer of the X-BT threaded fastener.

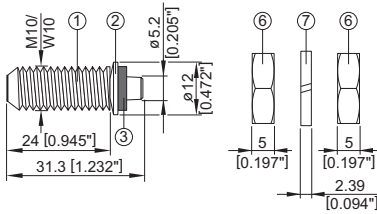
Note on corrosion resistance:

The corrosion resistance of stainless steel material, such as the duplex steel 1.4462 of the new generation X-BT threaded fasteners, is also affected by temperatures beyond 300 °C. However, as the maximum service temperature is determined by 100 °C concerning the sealing washer, the limit of 300 °C related with the durability of the stainless material is in general not relevant.

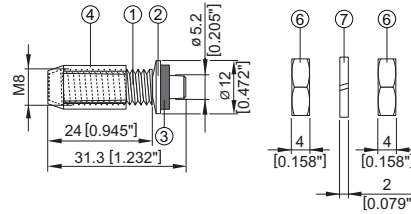
5.8 X-BT-ER stainless steel threaded studs electrical performances

Fasteners

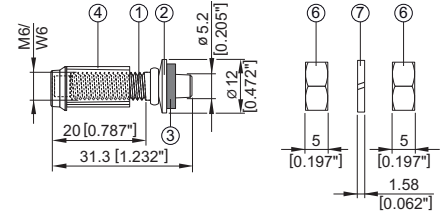
X-BT-ER M10/7 SN 8
X-BT-ER W10/7 SN 8



X-BT-ER M8/7 SN 8



X-BT-ER M6/3 SN 8, (X-BT-ER M6/7 SN 8)
X-BT-ER W6/3 SN 8, (X-BT-ER W6/7 SN 8)



Test Report No. 09-IK-0208: Suitability of Hilti X-BT-ER threaded studs as connection point in protective grounding and earthing circuits and for lighting protection; Electrosuisse; May 22, 2015

Test Report No. 09-IK-0208.32V2_e; Electrosuisse, Fehraltorf, Switzerland; May 2010

Amtec report 3028883: Finite Element Analysis: X-BT-ER stainless steel threaded stud for electrical connections, Lauffen, Germany, Nov 18, 2015

Report No. XE-15-105, "Simulation results: fastening process of XT-BT threaded stud with blunt tip", Simon Stahel, Schaan, Liechtenstein, October 2015

Test Report No. CF-791; Dehn und Söhne GmbH, Neumarkt, Germany; March 2006 Test Report No. 70064671; TÜV Test Centre, Frankfurt, Germany; March 2004

Expert's Report 17-IK-0260.S01: Suitability of Hilti X-BT-ER threaded studs as connection point in protective grounding and bonding circuits and for lightning protection, Electrosuisse, November 22, 2017

Report No. FRM - 1659 (2017): Test object: Threaded stud for coated steel X-BT M10 Types, Dehn & Söhne, Neumarkt, 17. March 2017

The new generation X-BT threaded studs have a stronger shank diameter (5.4 mm) than the previous generation of X-BT studs (4.5 mm). Therefore, the electrical properties of the new generation are at least equivalent with those of the previous generation X-BT threaded fasteners.

The electrical tests performed with the previous generation X-BT fasteners are summarized below. The sections are taken from the "X-BT Threaded Fastener Specification", July 2015. Those results are conservatively applied for the new generation X-BT threaded fasteners.

5.8.1 Contact resistance

Resistance of stud in cold condition, according to IEC 60947-7-2:
< 5 mΩ

5.8.2 Effect of X-BT-ER fasteners on integrity of pipe flanges

Installation of a Hilti X-BT(-ER) threaded stud is not expected to have negative influence on the integrity of flanged pipe joints made from typical ductile steel materials, when installed in the outer area of the pipe flange between 2 tension bolts.

Hilti's recommendations for edge distance, spacing, minimum flange diameter and minimum base material thickness, as well as Hilti's printed literature, must be considered during design and installation.

- Outer diameter of pipe flange is greater than or equal to 150mm (6 inches)
- Minimum edge distance = 6mm, i.e. minimum pipe flange thickness = 12mm
- X-BT-ER installed on center of pipe flange and between 2 tension bolts

5.8.3 Permanent current

For low permanent current due to static charge built up in pipes or for low permanent current when closing an electrical circuit.

Test standard	IEC EN 60204-1:2006	
Test criteria	<p>The temperature of the fastening point should not exceed the limits of the cable under permanent current, e.g. 70°C (environmental temp at 40°C) for PVC cables.</p> <p>Test duration: till temperature stability is reached.</p>	

Tested configuration	Tested Fasteners	Test results		
		Current	Max. temp (in° C)	Result
<p>Single point connection</p>	Tests performed with X-BT-ER fastener with shank diameter of 4.5mm	22 A	32.0° C	pass
		32 A	39.1° C	pass
		40 A	48.9° C	pass
		60 A	78.8° C	failed

Note: At 60 A, which is deduced from a protective grounding cable with cross section of 16 mm² (EN 60204-1; Tab 6), the maximally permissible temperature for PVC cables was exceeded for the connection. The maximum temperature permissible under normal condition is 70°C.

Conclusions

Based on permanent current withstand ability			
Current (max.)	Max. temp (in° C)	Connection configuration	Note: If the fastener is used in an environment and with cables which are heat resistant up to at least 90°C, then permanent currents up to 60 A can be applied.
40A	48.9° C	Single point connection	

or

Based on wire sizes as per EN 60204-1:1997			
Wire size (max.)	Current	Connection configuration	Note: If the fastener is used in an environment and with cables which are heat resistant up to at least 90°C, then wire sizes up to 16 mm ² can be used.
10 mm ² (8 AWG)	40A	Single point connection	

This summary is intended to be representative of the test(s) carried out. It is not intended to be a full and complete test report.

5.8.4 Short circuit current

For discharging short circuit current while protecting electrical equipment or earth / ground or bonded cable trays and ladders

Test standards	Requirements or test criteria	
IEC 61000-5-2	<ul style="list-style-type: none"> Tight contact between bonding strap terminal and equipment frame due to low electrical impedance Durably resistant to vibration Durably resistant to corrosion Durably resistant to mechanical forces and pull out forces 	pass
IEC EN 60947-7-2	<ul style="list-style-type: none"> A grounding connection must be capable of withstanding a high test current (I_{test}) for an exposure time of 1 second. $I_{test} = A_{cable} [mm^2] \times 120 [A/mm^2]$ <p>where A_{cable} = cross sectional area of the attached cable, i.e for wire size 10 mm², a current of 1200 A for exposure time of 1 second</p>	
UL 467	<ul style="list-style-type: none"> The grounding connection must be capable of withstanding a high test current (I_{test}) for a specified exposure time. <p>Table 14.1, e.g.</p> <ul style="list-style-type: none"> 14 AWG (2.1mm²) 300A for 4s 12 AWG (3.3mm²) 470A for 4s 10 AWG (5.3mm²) 750A for 4s 8 AWG (8.4mm²) 1180A for 4s 	

Tested configuration	Tested Fasteners	Test results		
		Current	Exposure time	Result
<p>Single point connection</p>	Tests performed with X-BT-ER fastener with shank diameter of 4.5mm	1400 A (IEC)	1 s	pass
		750 A (UL)	4 s	pass
		Note: Higher currents for a longer exposure time will result in failed connection.		
<p>Double point connection</p>	Tests performed with X-BT-ER fastener with shank diameter of 4.5mm	2240 A (IEC)	1 s	pass
		Note: Higher currents for an exposure time of 1 s will result in failed connection		

This summary is intended to be representative of the test(s) carried out. It is not intended to be a full and complete test report.

Conclusions for new generation X-BT-ER threaded fasteners

Based on short term current withstand ability (irrespective of wire size)			
Current (max. recommended)	Exposure time	Fastener	Connection configuration
1250 A	1 s	X-BT-ER M10/7 SN 8 X-BT-ER W10/7 SN 8	Single point connection
750 A	4 s	X-BT-ER M8/7 SN 8 X-BT-ER M6/7 SN 8 X-BT-ER W6/7 SN 8 X-BT-ER M6/3 SN 8 X-BT-ER W6/3 SN 8	
1800 A	1 s	X-BT-ER M10/7 SN 8 X-BT-ER W10/7 SN 8 X-BT-ER M8/7 SN 8 X-BT-ER M6/7 SN 8 X-BT-ER W6/7 SN 8	Double point connection

or

Based on wire sizes as per IEC 60947-7-2 & UL 467 (irrespective of current withstand ability)		
Wire size (max.)	Fastener	Connection configuration
10 mm ² (IEC) 10 AWG (UL)	X-BT-ER M10/7 SN 8 X-BT-ER W10/7 SN 8 X-BT-ER M8/7 SN 8 X-BT-ER M6/7 SN 8 X-BT-ER W6/7 SN 8 X-BT-ER M6/3 SN 8 X-BT-ER W6/3 SN 8	Single point connection
16 mm ² (IEC)	X-BT-ER M10/7 SN 8 X-BT-ER W10/7 SN 8 X-BT-ER M8/7 SN 8 X-BT-ER M6/7 SN 8 X-BT-ER W6/7 SN 8	Double point connection

This summary is intended to be representative of the test(s) carried out. It is not intended to be a full and complete test report.

5.8.5 Lightning current

For high temporary current due to lightning.

Test standard	Test criteria
<p>IEC 50164-1: 1999 “Lightning protection components Part 1: Requirements for connection components” and EN 50164-1 / prA1:2005</p>	<p>Electrical test with stress of 3 times 50 or 100 kA (signal form 10/350 μs) lightning current as follows:</p> <ul style="list-style-type: none"> • class H $I_{max} = 100 \text{ kA} \pm 10 \%$ $W/R = 2,5 \text{ MJ}/\Omega \pm 20 \%$ $t_d \leq 2 \text{ ms}$. • class N $I_{max} = 50 \text{ kA} \pm 10 \%$ $W/R = 0,63 \text{ MJ}/\Omega \pm 20 \%$ $t_d \leq 2 \text{ ms}$.

Tested configuration	Tested fasteners	Test results			
		Current	Exposure time	Contact resistance	Result
<p>Single point connection</p>	<p>Tests performed with X-BT-ER fastener with shank diameter of 4.5mm</p>	50 kA	2 ms	< 5 m Ω	pass
		Note: Higher currents for an exposure time of 2 ms will result in failed lightning connection.			

Tested configuration	Tested fasteners	Test results			
		Current	Exposure time	Contact resistance	Result
<p>Single point connection*</p>	<p>Tests performed with X-BT-ER fastener with shank diameter of 4.5mm</p>	100 kA	2 ms	< 5 m Ω	pass
		Note: Higher currents for an exposure time of 2 ms will result in failed lightning connection.			

* In this connection configuration, the X-BT-ER is used as a fastener and not as an electrical conductor. The cable lug must be in direct contact with non-coated base material. Please refer to requirements in **2.6.3**.

Conclusions for new generation X-BT-ER threaded fasteners

Based on EN 50164-1:1999 and EN 50164-1 / prA1:2005			
Current (max.)	Exposure time	Fastener	Connection configuration
50 kA	2 ms	<p>X-BT-ER M10/7 SN 8 X-BT-ER W10/7 SN 8 X-BT-ER M8/7 SN 8 X-BT-ER M6/3 SN 8 X-BT-ER W6/3 SN 8 X-BT-ER M6/7 SN 8 X-BT-ER W6/7 SN 8</p>	<p>Single point connection</p>

Based on EN 50164-1:1999 and EN 50164-1 / prA1:2005			
Current (max.)	Exposure time	Fastener	Connection configuration
100 kA	2 ms	<p>X-BT-ER M10/7 SN 8 X-BT-ER W10/7 SN 8 X-BT-ER M8/7 SN 8</p>	<p>Single point connection*</p>

* In this connection configuration, the X-BT-ER is used as a fastener and not as an electrical conductor. The cable lug must be in direct contact with non-coated base material. Please refer to requirements in **2.6.3**.

5.9 X-BT in stainless steel base material

The same aspects are to be considered for the new generation X-BT threaded fasteners as for the previous generation of X-BT threaded fasteners.

Therefore, the following recommendations summarizing the use of X-BT in stainless steel taken from the “X-BT Threaded Fastener Specification”, July 2015, also apply for the new generation X-BT threaded fasteners (together with the respective new drill TX-BT 4.7/7).

Report:

Hilti internal report XE-07-26; Buhri R., 2007-05-21

Stainless steel is very hard, so the drilling technique differs from that used for structural steel, the material for which the X-BT system has been optimized.

Driving the X-BT stud in stainless steel presents no problem, but drilling is decisive.

Test material and conditions

Type of drill bit:	Standard TX-BT 4/7 step shank drill bit Two special shank drill bits for stainless steel
Type of stainless steel material:	Material number: 1.4401, 1.4462, 1.4529, 1.4539
Drilling procedure:	Wet or dry
Number of tests:	495 drilling operations with 28 drill bits
Condition:	Hand held operation, same as the standard operation

Results

- With all of the stainless steel materials tested, the standard TX-BT 4/7 drill bit was found to perform better than special drill bits.
- Cooling the drill bit does not lead to better results.
- Use of a corded electric drill is recommended due to the longer drilling time.
- Best results are achieved with a corded drill set to a speed of 1000 r.p.m.
- To achieve satisfactory drilling performance, much higher pressure must be applied to the drill bit.
- About 25 to 35 holes can be drilled with a TX-BT 4/7 drill bit.
- Characteristic pull-out loads are in the 8 to 16 kN range, which provides an adequate safety factor for the recommended loads. (Note: Results refer to previous generation of X-BT threaded fasteners)

Recommendation

For making fastenings in stainless steel with new generation Hilti X-BT studs, we recommend use of the standard TX-BT 4.7/7 drill bit with a drill tool having a speed close to 1000 r.p.m.

The following Hilti models are suitable:

- UD 30 – set at gear 1 @ 1200 r.p.m
- UH 700 – set at gear 1 @ 900 r.p.m
- SF 22-A – set at gear 2 @ 1250 r.p.m (cordless tool)

5.10 X-BT under shock loading

Due to the similarity in the anchorage mechanism, the same shock behavior is expected for the new generation X-BT threaded fasteners as for the previous generation of X-BT threaded fasteners.

Therefore, the test information on shock tests performed with the previous generation of X-BT threaded fasteners, taken from the “X-BT Threaded Fastener Specification”, July 2015, is reported as follows:

Shock tests with X-BT studs and MQ channel systems fastening electrical cable and pipe runs are described in these documents:

- Test certificate number QUINETIQ/CMS/TC040089
- QinetiQ Shock Test Laboratory, 15.01.2004
- Report 2004-CMC-R017, TNO Delft, Netherlands, 29.05.2005

Mechanical and electrical equipment fastened with MQ channels and X-BT studs tested under shock load.

- Small-bore pipe runs
- High-voltage cable runs
- T-bars for fastening high-voltage cables
- Cable basket electrical runs
- Cable tray electrical runs

All applications were tested with an effective acceleration of 1844 m/s^2 in the three orthogonal axes, in horizontal (longitudinal and side to side) and vertical direction. In another test, X-BT studs with a mass of 3 kg each were installed on a shock test rig and tested with a maximum effective acceleration of 4905 m/s^2 .

Test results

- The channel system, the X-BT studs and the attached equipment remained captive at all times.
- The tested effective acceleration of 1844 m/s^2 corresponds to a shock load of 188 G.
- The X-BT with a fastened mass of 3 kg withstood a shock load of 200 G in horizontal (shear) and 500 G in longitudinal (tension) direction.

Lightweight high impact shock testing of Hilti X-BT studs for electrical cable holder, electrical box and slotted channel installations are also described in HI-TEST LABORATORIES, INC., Report No. 1475, April 30, 2007.

X-BT stud fastened assemblies were subjected to lightweight high impact shock tests in accordance with MIL-S-901D (NAVY) and HI-TEST Procedure No. HT-1780-TP-1, Revision “-”.

Testing was conducted at HI-TEST LABORATORIES, INC., Arvon, Virginia, using their standard Navy shock testing machine for lightweight equipment.

HI-TEST LABORATORIES, INC. is approved for class H.I. (High Impact) shock testing by NAVSEA per NAVSEAINST 9491.1C dated 21 March 1996. Nine blows were applied to each test item - three blows in each of the three mutually perpendicular axes of the test item (from the top, back, and side) at hammer heights of 1, 3, and 5 feet. Two separate lightweight shock tests were performed, one for each test panel. Shock test accelerations ranged from 80 to 300 G's.

Test Results

There was no evidence of broken or loose parts during the test series. There was also no evidence of damage to the test cables that could be considered an electrical hazard.



Test configuration: Two base plates were populated with MQ channel fastened with X-BT studs. The base plates were rigidly attached to the 2-tonne shock loading machine.

5.11 X-BT stud in steel with a thickness of less than 8 mm

5.11.1 Pull-out capacity in thin steel

Evaluation report on new generation Hilti X-BT-GR, X-BT-MR and X-BT-ER threaded fasteners,

Hilti Report XE-18-12, Beck H., 2018-05-22

The characteristic pull-out resistance of new generation X-BT threaded studs reduces with base material thickness. Below 8 mm base material through penetration of the base material is possible. The minimum base material thickness amounts to 4 mm. Test data confirmed that the same linear reduction with the factor α – as for the previous generation X-BT threaded fasteners – results in a conservative prediction of the tension resistance.

$$\text{Reduction factor: } \alpha = \frac{t_{II} - 2}{6}$$

with t_{II} = thickness of base steel, $4 \text{ mm} \leq t_{II} \leq 8 \text{ mm}$

Example: For a base steel thickness of 6 mm, the recommended loads using global safety factors are:

Steel S235 / ASTM A36: $N_{\text{rec},6} = 3.6 \cdot (6-2)/6 = 2.40 \text{ kN}$

Steel S355 / Grade 50: $N_{\text{rec},6} = 4.6 \cdot (6-2)/6 = 3.05 \text{ kN}$

Recommended tightening torque T_{rec}

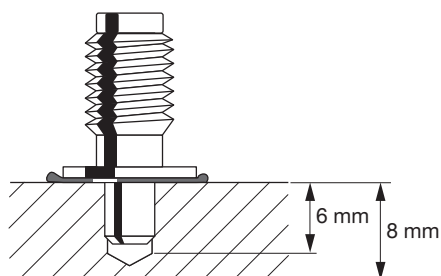
- For base material thickness $6 \leq t_{II} < 8 \text{ mm}$, the tightening torque $T_{\text{rec}} \leq 20 \text{ Nm}$ is recommended (such as for base material thickness $t_{II} \geq 8 \text{ mm}$).
- For base material thickness $4 \leq t_{II} < 6 \text{ mm}$, the tightening torque $T_{\text{rec}} \leq 8 \text{ Nm}$ is recommended.

5.11.2 Shear load capacity in thin steel

Tension and shear tests with Hilti stud X-BT-GR M8/7 SN 8

Report 254/17, HTL-Rankweil (2017), Wechner W., 2017-12-04

Test results performed in 6 mm base material resulted to high shear resistances very similar with the performance in 8 mm thick base material. Conservatively, the same reduction factors α as for tension loads are recommended to be used.



5.11.3 X-BT-ER electrical conductivity in thin steel

Reduction of the base material thickness to 6 mm will result in the same contact area between the shank of the stud and the base material as with 8 mm material (see drawing with previous generation X-BT threaded fastener). The embedment depth of the stud is within the 4.5 to 5.6 mm range.

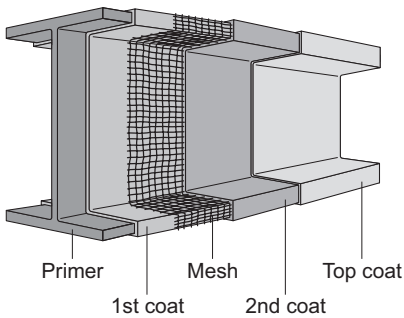
Due to this, a reduction in electrical conductivity in 6 mm base steel is not expected because the main parameter for electrical conductivity is the contact area between base steel and the X-BT-ER stud. It must be noted that no electrical conductivity tests have been carried out for base steel with a thickness of less than 8 mm. The above statement is based on an engineering judgment only.

General note

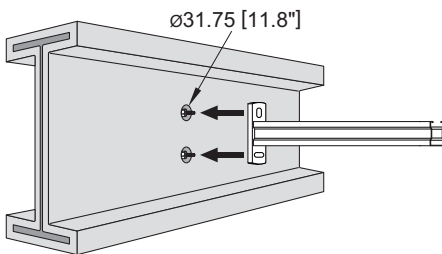
With a base steel thickness of less than 8 mm, it can no longer be ensured that corrosion protection on the reverse side of the steel plate remains intact.

This summary is intended to be representative of the test(s) carried out. It is not intended to be a full and complete test report.

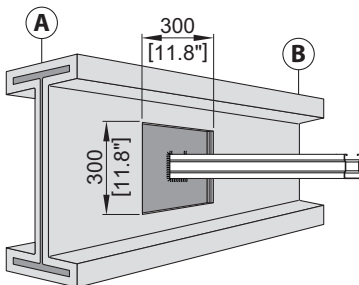
5.12 X-BT ON STRUCTURAL STEEL WITH PASSIVE FIRE PROTECTION (PFP) COATING



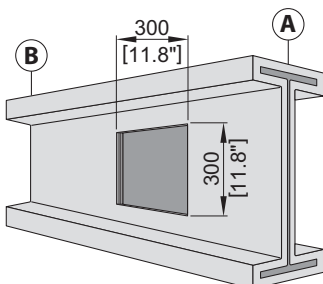
Passive fire protection (PFP) coating in steel construction



Fastening with X-BT and standoff adapter



Welding method (front)



Welding method (back)

5.12.1 Introduction

Structural steel with passive fire protection (PFP) coatings are often encountered in onshore and offshore facilities, e.g. for load-bearing structures supporting tanks, pipelines and electrical equipment. Herein, the PFP seeks to slow down fire propagation and extend the structural integrity of the coated members.

Out of a wide range of coatings that can be used to make a structure more fire-resistant, the proposed fastening method refers to intumescent coatings that are commonly used in on- and offshore applications due to their advantages in terms of ease of installation and performance. These epoxy-based coatings come in a thickness range ≤ 20 mm [0.78"] either mesh free or with a carbon fiber mesh. When exposed to fire their volume expands creating a thermo-insulating barrier.

The proposed fastening method uses direct fastening solution together with standoff adapters (figure 1.2) as an alternative to welding (figure 1.3 and 1.4) and boxing methods of attachment to PFP-coated structural steel.

The local PFP-coating removal is done with a special drill bit. Then the X-BT fastener is installed allowing a standoff adapter to be screwed on, therefore allowing a fastening point above the coating.

5.12.2 Features and benefits

Simple and fast:

The method proposed utilizes mechanical fasteners and battery tools. Minimal training is required for a user to be able to install up to 25 fastening points per hour.

Reduced influence on integrity of fireproofing

Per fastening point only 791 mm² [1.23 sqin] of PFP-coating is removed with a heat conducting cross-section of 16 mm² [0.03 sqin]. Additionally, in the case of less than four fastening points per meter length or per square meter of surface area, the integrity of the PFP-coating may not be comprised [2]. Please verify with your local regulations and PFP-coating supplier.

High corrosion resistance:






The stainless steel standoff adapters are made from the austenitic stainless steel type 1.4401, AISI 316 (A4) grade and suitable for aggressive environments like in coastal and offshore applications.

The coating of the carbon steel standoff adapters consists of an electroplated Zn-alloy for cathodic protection and a top coat for chemical resistance (Duplex-coating). The use of this coating is limited to indoor environments and outdoor (non-coastal) environments with low pollution.

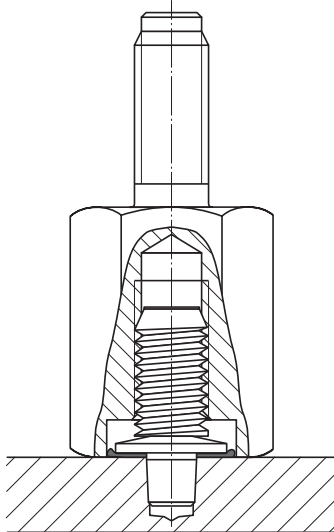
Cordless and Portable:

The cordless drilling and installation tools eliminate the need for electrical cords and heavy welding equipment.

5.12.3 Fastener program

System component	Item no.	Designation	Image
Threaded stud	2194344	X-BT-GR M8/7 SN8	
	2194340	X-BT-MR M10/15 SN8, incl. flange nut	
	2194341	X-BT-MR W10/15 SN8, incl. flange nut	
Standoff adapter	2268522	Adapter M8-MR25, incl. wide M8 flange nut	
	2268523	Adapter M8-MR50, incl. wide M8 flange nut	
	2268524	Adapter M8-MR75, incl. wide M8 flange nut	
	2268525	Adapter M8-MR100, incl. wide M8 flange nut	
	2281193	Adapter M10-MR50	
	2281191	Adapter W10-MR50	
	2268526	Adapter M8-MF25, incl. wide M8 flange nut	
	2268527	Adapter M8-MF50, incl. wide M8 flange nut	
	2268528	Adapter M8-MF75, incl. wide M8 flange nut	
	2268529	Adapter M8-MF100, incl. wide M8 flange nut	
	2281194	Adapter M10-MF50	
	2281192	Adapter W10-MF50	
Drill bit	2310192	TX-BT31-74 PFP (not pictured)	
Tool	2194595	BX3-BT	
	2194592	BX3-BTG	
	377613	DX351 BT	
	377616	DX351 BTG	
	2123719	SFBT22-A	
	2119272	Torque tool X-BT 1/4" – 8 Nm	
	2212510	Torque tool X-BT 1/4" – 20 Nm	
Nutsetter	2149244	S-NS13 C95/3 3/4"	
	2149245	S-NS15 C95/3 3/4"	
	2149246	S-NS9/16" C95/3 3/4"	
	2268521	S-NS3/4" 95/3 3/4"	
Bored plate	304071	Bored Plate MQZ-L9-R	
	304196	Bored Plate MQZ-L9-F	
	304072	Bored Plate MQZ-L11-R	
	304197	Bored Plate MQZ-L11-F	

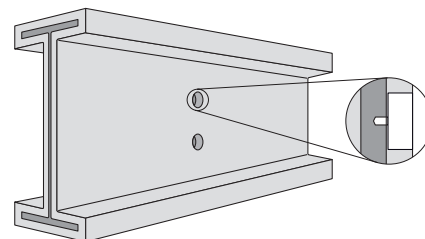
5.12.4 Fastener and standoff adapter combinations



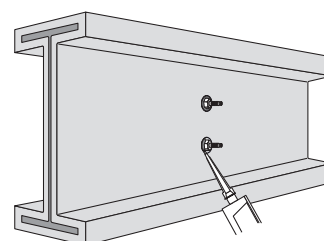
Fastener	Standoff adapter	Material	Standoff length
X-BT-GR M 8/7 SN 8	Adapter M 8-MR 25	Stainless steel	25 mm [1"]
	Adapter M 8-MR 50	Stainless steel	50 mm [2"]
	Adapter M 8-MR 75	Stainless steel	75 mm [3"]
	Adapter M 8-MR 100	Stainless steel	100 mm [4"]
	Adapter M 8-MF 25	Carbon steel	25 mm [1"]
	Adapter M 8-MF 50	Carbon steel	50 mm [2"]
	Adapter M 8-MF 75	Carbon steel	75 mm [3"]
	Adapter M 8-MF 100	Carbon steel	100 mm [4"]
X-BT-MR M 10/15 SN 8	Adapter M 10-MR 50	Stainless steel	50 mm [2"]
	Adapter M 10-MF 50	Carbon steel	50 mm [2"]
X-BT-MR W 10/15 SN 8	Adapter W 10-MR 50	Stainless steel	50 mm [2"]
	Adapter W 10-MF 50	Carbon steel	50 mm [2"]

5.12.5 Installation information

- 1) Mark each fastening position.
- 2) Remove PFP and pre-drill with TX-BT PFP stepped drill bit, use SFBT22-A until the bit shoulder exposes steel and the shoulder grinds a shiny ring to ensure a proper drilling depth (figure 3.1).
Result is a circle of exposed steel with \varnothing 6.5 mm as well as a maintaining surrounding coating thickness \leq 500 μ m.
- 3) Set the X-BT stud into the drilled hole, use BX 3-BT(G), check standoff with check card.
- 4) Screw stand-off adapter on the X-BT fastener, use nut setter S-NS 3/4" 95/3 3/4" in combination with torque tool X-BT 1/4" – 8 Nm or Hilti screw drivers with correct torque setting.
- 5) Repair removed PFP-coating outside of standoff adapter.
Prevent delamination of PFP-coating as well as exposure of underlying steel beam by patching area outside of standoff adapter in accordance to the patching instructions by the PFP-coating manufacturer (figure 3.2).
- 6) Position channel or accessory on standoff adapter.
Use bored plate MQZ-L9/11/R as required to increase contact surface and/or center channel on the standoff adapter. Tighten nut by hand.
- 7) Tighten the nut with recommended torque moment.
Usage of nut setter according to the nut diameter in combination with torque tool X-BT 1/4" – 20 Nm or Hilti screw drivers with correct torque setting.



Shiny ring control after PFP-removal



PFP-coating repair

	Torque moment T_{rec}	
	8 Nm	20 Nm
Hilti screw driver	Torque setting	Torque setting
SBT 4-A22	7	11
SF 4-A22	10	-
SFC 18-A	5	11
SFC 22-A	5	11

Note:

Exceeding the tightening torque (T_{rec}) leads to damage of the X-BT stud anchorage with negative impact on the load values and the sealing function.

5.12.6 Standoff adapter material specifications and dimensions

	Stainless steel M8-MR 25/50/75/100	Carbon steel M8-MF 25/50/75/100
Adapter	① Stainless steel (X5CrNiMo17-12-2) 1.4401-AISI 316	② Carbon steel (11SMnPb37+C) duplex-coated
Flange nut	⑤ Stainless steel grade A4 - 70/80	⑥ Carbon steel HDG, grade 8
Adapter M8-MR25 Adapter M8-MR50 Adapter M8-MR75 Adapter M8-MR100 Adapter M8-MF25 Adapter M8-MF50 Adapter M8-MF75 Adapter M8-MF100		
Adapter M10-MR50 Adapter M10-MF50 Adapter W10-MR50 Adapter W10-MF50		
Flange nut		

5.12.7 Corrosion information

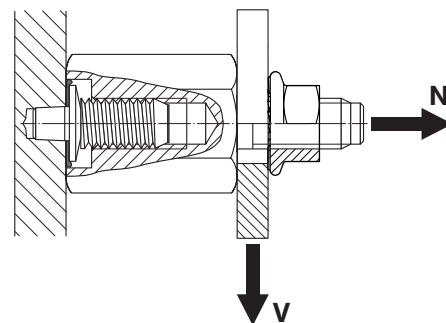
The stainless steel standoff adapters are made from the stainless steel type 1.4401 (AISI 316). This grade of stainless steel is classified as corrosion resistance class III according to DIN EN 1993-1-4:2015, which makes the material suitable for outdoor applications and atmospheres containing chloride ions, i.e. coastal areas and areas near roads treated with de-icing salts.

The coating of the carbon steel standoff adapters consists of an electroplated Zn-alloy for cathodic protection and a top coat for chemical resistance (Duplex-coating). The use of this coating is limited to the corrosion category C1, C2 and C3 according to the standard EN ISO 9223. For higher corrosion categories stainless steel standoff adapters should be used.

5.12.8 Load data with standoff adapter

Recommended resistance under tension load, shear load and torque moment

Resistance under tension, shear load and torque moment	Standoff adapter	Steel grade	
		S 235, A 36	S 355, S 420 Grade 50
N_{rec}	25, 50, 75, 100 mm	3.60 kN/810 lb	4.60 kN/1035 lb
V_{rec}	25 mm	1.14 kN/255 lb	1.43 kN/320 lb
V_{rec}	50 mm	0.62 kN/140 lb	0.78 kN/175 lb
V_{rec}	75 mm	0.52 kN/115 lb	0.65 kN/145 lb
V_{rec}	100 mm	0.35 kN/80 lb	0.44 kN/100 lb
T_{rec}	25, 50, 75, 100 mm	20.00 kN/14.80 lb	20.00 kN/14.80 lb



Condition:

- Working load design concept (e. g. ASD).
- Use X-BT-MR and X-BT-GR only with the Hilti standoff adapter M 8-MF/R, M 10-MF/R.
- For unalloyed construction, offshore and shipbuilding steel: e.g. European grades according to EN 10025-4 or EN 10225, US steel grade A36 and Grade 50.
- Minimum base material thickness $t_{II} = 8$ mm.
- Applicable for steel base materials up to a remaining coating thickness after PFP-removal of 500 μ m.
- Edge distance $c \geq 10$ mm [3/8"].
- Redundancy (multiple fastening) must be provided.
- Global safety factor for tension and shear load = 2.8 related to the characteristic resistance N_{Rk} and V_{Rk} .

Design resistance under tension load and shear load

Resistance under tension and shear load	Standoff adapter	Steel grade	
		S 235, A 36	S 355, S 420, Grade 50
N_{Rd}	25, 50, 75, 100 mm	5.00 kN/1120 lb	6.50 kN/1460 lb
V_{Rd}	25 mm	1.60 kN/360 lb	2.00 kN/450 lb
V_{Rd}	50 mm	0.87 kN/195 lb	1.09 kN/245 lb
V_{Rd}	75 mm	0.73 kN/165 lb	0.91 kN/205 lb
V_{Rd}	100 mm	0.49 kN/110 lb	0.61 kN/135 lb

Supplemental condition:

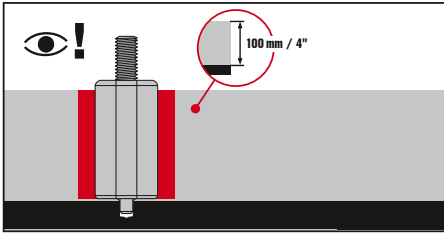
- Design load can be used for the design according to the partial safety concept, e.g. EN 1993-1-1 (Eurocode 3).
- Maximum displacement in shear load direction ≤ 2.0 mm [0.08"]
- Design resistances N_{Rd} and V_{Rd} are determined from the characteristic resistance N_{Rk} and V_{Rk} applying a partial safety factor $\gamma_M = 2.0$.

5.12.9 METHOD STATEMENT - INSTRUCTION FOR USE

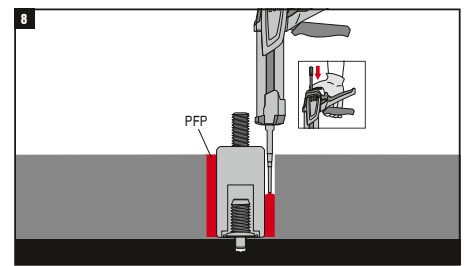
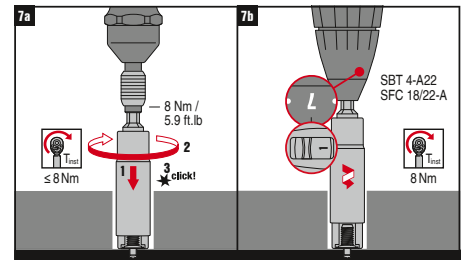
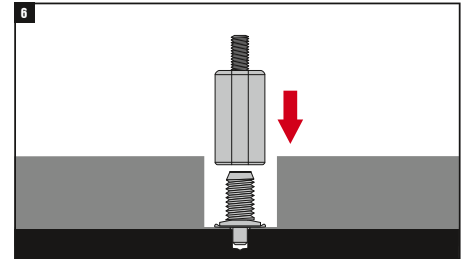
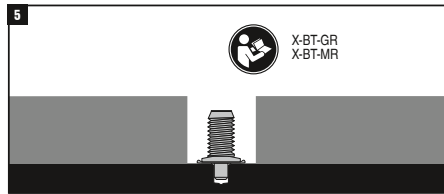
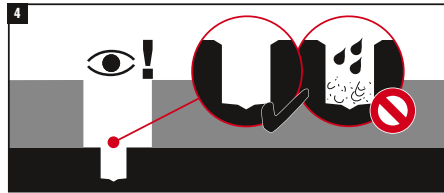
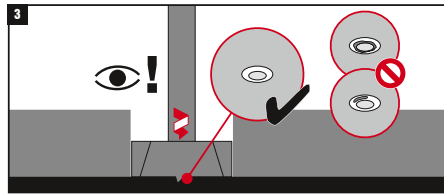
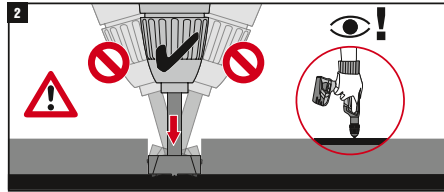
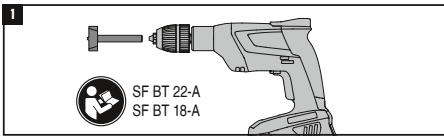
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Hilti Corrosion handbook / DFTM



	M8 MR/MF 25		BX 3-BT(G)
	M8 MR/MF 50		DX 351-BT(G)
	M8 MR/MF 75		
	M8 MR/MF 100		
	M10 MR/MF 50		S-NS 19
	W10 MR/MF 50		
	X-BT-GR M8/7 SN 8		SBT 4-A22
	X-BT-MR M10/15 SN 8		SFC 18/22-A
	X-BT-MR W10/15 SN 8		
	Torque tool X-BT 1/4 8Nm / 5.9ft.lb		SF BT 22-A
			SF BT 18-A



5.12.10 LITERATURE

[1] Steel Construction Institute (SCI), Fire Loading and Structural Response (FABIG Technical Note 11); 2009

5.13 Chemical resistance of SN sealing washer

(X-BT sealing washer)

Chemicals	Volum swell					
	<20%	20-40%	>40-60%	60-80%	>80-100%	>100%
1. Water at 80°C	■					
2. Sea water	■					
3. Zinc chloride 10%	■					
4. Sodium chloride 15%	■					
5. Hydrochloric acid 10%	■					
6. Acetic acid	■					
7. Acrylonitrile				■		
8. Aniline				■		
9. n-Butyl acetate					■	
10. Diethylether		■				
11. Ethanol	■					
12. Glycerol	■					
13. n-Hexane	■					
14. Methanol	■					
15. Methylethylketone				■		
16. Nitrobenzene				■		
17. 1-Propanol	■					
18. Oil (ASTM-1) at 80°C	■					
19. Oil (ASTM-2) at 80°C		■				
20. Oil (ASTM-3) at 80°C		■				
21. Reference fuel B (isooctane/toluene, 70/30)				■		
22. Reference fuel C (isooctane/toluene, 50/50)					■	
23. Hydraulic brake fluid	■					
24. Hydraulic brake fluid at 100°C		■				
25. Antifreeze (ethylene glycol/water 50/50) at 125°C		■				

Material: 3.1107 Elastomer: CR ozone and UV resistance Temperature range: -40°C to +100°C

Volume swelling is a reaction of the material of the washer when it's in contact with the different substances. It's used as a parameter to describe the chemical reaction.

The swelling factor gives an indication of the behavior of the material, but swelling does not lead directly to loss of the sealing property. With an installed stud, the washer is compressed against the base steel.

Without any specific requirement it can be stated that the washer is resistant to all substances where the volume swelling value is not above 20 to 40%.

5.14 Material safety data sheet for SN sealing washer acc. to ISO/DIS 11014

5.14.1 Identification of substance

Product details

Trade name: Plate 2.0x650x50.000 mm OE 3.1107

Application of the substance / the preparation: Rubber compound

Manufacturer/supplier:

PHOENIX CBS GmbH, Hannoversche Straße 88, D-21079 Hamburg

Information department:

Conseo GmbH Abteilung Umweltschutz, Hannoversche Straße 88

D-21079 Hamburg, 040 32809 2794

Emergency information:





0049(0)40 7667 2233

5.14.2 Composition/data on components

Chemical characterization

Description: Mixture of the substances listed below with non-hazardous additions

Dangerous components

117-81-7	bis(2-ethylhexyl) phthalate	 T; R 60-61	2.5-10%
1309-48-4	magnesium oxide		2.5-10%
1314-13-2	zinc oxide		2.5-10%
68953-84-4	N,N'-Diaryl-p-phenyldiamine	 Xi,  N; R 43-50/53	≤ 1.0%
97-39-2	1,3-di-o-tolylguanidine	 T; R 25	≤ 1.0%

Additional information: For the wording of the listed risk phrases refer to section 16.

5.14.3 Hazards identification

Hazard description **U**

Information pertaining to particular dangers for man and environment:

The product has been classified in accordance with EU directives / national laws respectively. In the version marketed, it presents no risk to the environment or to health. Following directive 67 / 54 8 EC, annex VI, point 9.3 it is not necessary to be labelled.

Classification system

The classification was made according to the latest editions of international substances lists and expanded upon from company and literature data.

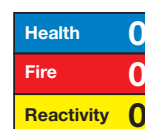
NFPA ratings (scale 0–4)

Health = 0, Fire = 0, Reactivity = 0



HMIS-ratings (scale 0–4)

Health = *0, Fire = 0, Reactivity = 0



5.14.4 First aid measures

General information: No special measures required.

After inhalation: Supply fresh air; consult doctor in case of complaints.

After skin contact: Generally the product does not irritate the skin.

After eye contact: Rinse opened eye for several minutes under running water.

After swallowing: If symptoms persist consult doctor.

5.14.5 Fire fighting measures

Suitable extinguishing agents:

CO₂, extinguishing powder or water spray. Fight larger fires with water spray or alcohol resistant foam.

Special hazards caused by the material, its products of combustion or resulting gases:

Formation of toxic gases is possible during heating or in case of fire.

In case of fire, the following can be released:

Carbon monoxide (CO), Sulphur dioxide (SO₂), Hydrogen chloride (HCl)

Protective equipment: No special measures required.

5.14.6 Accidental release measures

Person-related safety precautions: Not required.

Measures for environmental protection: No special measures required.

Measures for cleaning/collecting: Pick up mechanically.

Additional information: No dangerous substances are released.

5.14.7 Handling and storage

Handling

Information for safe handling: No special measures required.

Information about protection against explosions and fires:

No special measures required.

Storage

Requirements to be met by storerooms and receptacles:

No special requirements.

Information about storage in one common storage facility: Not required.

Further information about storage conditions: None.

5.14.8 Exposure controls and personal protection

Additional information about design of technical systems:

No further data; see item 7.

Components with limit values that require monitoring at the workplace:

When working with the product N-nitrosamines can be liberated

117-81-7 bis(2-ethylhexyl) phthalate

PEL 5 mg/m³

REL Short-term value: 10 mg/m³
Long-term value: 5 mg/m³

TLV 5 mg/m³

1309-48-4 magnesium oxide

PEL 15* mg/m³
fume

TLV 10 mg/m³
fume

1314-13-2 zinc oxide

PEL 15*; 5** mg/m³
Dust only *Total dust **Respirable dust

REL Short-term value: C 15*; 10** mg/m³
Long-term value: 5, 5** mg/m³
Zinc oxide, Dust only; *15-min Dust only; **Zinc

TLV Short-term value: 10** mg/m³
Long-term value: 10* 5** mg/m³
*dust **fume; *NIC-2 R; *10 R; *(e)

Additional information

The lists that were valid during formulation were used as a basis.

Personal protective equipment

General protective and hygienic measures:

The usual precautionary measures for handling chemicals should be followed.

Protection of hands

The glove material must be impermeable and resistant to the product / the substance / the preparation.

As no test information is available, no recommendation about glove material can be given for the product/ the preparation/ the chemical mixture.

Selection of the glove material on consideration of the penetration times, rates of diffusion and the degradation.

Glove material

Selection of suitable gloves does not only depend on the material, but also on further marks of quality and varies from manufacturer to manufacturer. As the product is a preparation of several substances, the resistance of the glove material can not be calculated in advance and must therefore be checked prior to the application.

Penetration time of glove material

The exact breakthrough time must be stated by the manufacturer of the protective gloves and must be observed.

Eye protection

Not required.

5.14.9 Physical and chemical properties

General Information

Form:	Solid
Color:	According to product specification
Odor:	Characteristic
Change in condition	
Melting point/melting range:	Undetermined.
Boiling point/boiling range:	Undetermined.
Flash point:	Not applicable.
Ignition temperature:	370.0°C (698°F)
Auto igniting:	Product is not self-igniting.
Danger of explosion:	Product does not present an explosion hazard.
Density at 20°C (68°F):	1.380 g/cm ³
Solubility in / miscibility with water:	
	Insoluble.
Solvent content:	
Organic solvents:	0.0 %
Solids content:	94.5 %

5.14.10 Stability and reactivity

Thermal decomposition / conditions to be avoided

No decomposition if used according to specifications.

Dangerous reactions

No dangerous reactions known.

Dangerous products of decomposition

Hydrogen chloride (HCl)

Toxic pyrolysis products.

5.14.11 Toxicological information

Acute toxicity

LD/LC50 values that are relevant for classification

117-81-7 bis(2-ethylhexyl) phthalate

Oral LD50 30600 mg/kg (rat)

Dermal LD50 25000 mg/kg (rbt)

Primary irritant effect

On the skin: No irritant effect.

On the eye: No irritating effect.

Sensitization: No sensitizing effects known.

Additional toxicological information

The product is not subject to classification according to internally approved calculation methods for preparations.

When used and handled according to specifications, the product does not have any harmful effects according to our experience and the information provided to us.

5.14.12 Ecological information

General notes

Generally not hazardous to water

5.14.13 Disposal considerations

Product

Recommendation

Smaller quantities can be disposed of with household waste.
Can be disposed of under observance of the technical instructions after consultation with the local authorities and waste disposers.
Use one of the following waste key numbers.

Uncleaned packagings

Recommendation: Disposal must be according to official regulations.

5.14.14 Transport information

DOT regulations:

Hazard class: -

Land transport ADR/RID (cross-border):

ADR/RID class: -

Maritime transport IMDG:

IMDG Class: -

Marine pollutant: No

Air transport ICAO-TI and IATA-DGR:

ICAO/IATA Class: -

Transport/additional information:

Not hazardous according to the above specifications.

5.14.15 Regulations

Sara

Section 355 (extremely hazardous substances):

None of the constituents are listed.

Section 313 (Specific toxic chemical listings):

117-81-7 bis(2-ethylhexyl) phthalate

TSCA (Toxic Substances Control Act):

9010-98-4 Polychloropren CR

117-81-7 bis(2-ethylhexyl) phthalate

1309-48-4 magnesium oxide

1314-13-2 zinc oxide

97-39-2 1,3-di-o-tolylguanidine

101-67-7 bis(4-octylphenyl)amine

97-74-5 tetramethylthiuram monosulphide

Proposition 65

Chemicals known to cause cancer:

117-81-7 bis(2-ethylhexyl) phthalate

Chemicals known to cause reproductive toxicity:

None of the constituents are listed.

Carcinogenicity categories**EPA (Environmental Protection Agency)**

117-81-7	bis(2-ethylhexyl) phthalate	B2
1314-13-2	zinc oxide	D

IARC (International Agency for Research on Cancer)

117-81-7	bis(2-ethylhexyl) phthalate	2B
----------	-----------------------------	----

NTP (National Toxicology Program)

117-81-7	bis(2-ethylhexyl) phthalate	R
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TLV (Threshold Limit Value established by ACGIH)

117-81-7	bis(2-ethylhexyl) phthalate	A3
----------	-----------------------------	----

MAK (German Maximum Workplace Concentration)

None of constituents are listed.

NIOSH-Ca (National Institute for Occupational Safety and Health)

117-81-7	bis(2-ethylhexyl) phthalate	
----------	-----------------------------	--

OSHA-Ca (Occupational Safety & Health Administration)

None of the constituents are listed.

Product-related hazard information

Observe the general safety regulations when handling chemicals.

The product has been classified in accordance with EU directives / national laws respectively.

In the version marketed, it presents no risk to the environment or to health.

Following directive 67 / 548 EC, annex VI, point 9.3 it is not necessary to be labelled.

Hazard symbols**U****National regulations****Technical instructions (air)**

Class	Share in %
I	0.4
NK	5.5

Water hazard class: Generally not hazardous to water.

Other regulations, limitations and prohibitive regulations

Subject to the regulations for N-Nitrosamines.

5.14.16 Other information

This information is based on our present knowledge. However, this shall not constitute a guarantee for any specific product features and shall not establish a legally valid contractual relationship.

Department issuing MSDS: Conseo GmbH Abteilung Umweltschutz

Contact: Hr. Dr. KräBig / Hr. Dr. Laugwitz



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