UIAA International Climbing and Mountaineering Federation
UNION INTERNATIONALE DES ASSOCIATIONS D'ALPINISME

DAV
Deutscher Alpenverein

Bolts

A guide to installing and replacing bolts on climbing routes

ENGLISH VERSION

Imprint

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Content


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Introduction

Bolts have been used for over 50 years in climbing and mountaineering. Especially in the past, bolts have often been a point of contention in passionate discussions about climbing ethics, because bolts make it possible to climb routes that would be impossible to protect without leaving a scar in the rock. This accessibility made possible by bolting accelerated the rapid development of modern sport climbing with routes up to the highest levels of difficulty. The sport of climbing thus changed from the exotic hobby of a few individuals to a popular sport thanks to the safety provided by bolts.

Again and again, accidents with failed and damaged bolts have been reported to the German Alpine Club (DAV); these bolts have been collected and evaluated by DAV Safety Research Department. The resulting knowledge has already been incorporated into the publication „More safety in mountaineering“ (Part 10) in 1995, and in 2009 the first „Bolt Brochure“ (Bohrhakenbroschüre) was published as a guide to bolt installation. Much has happened since then: bonding agents tested at the time for glue-in bolts are no longer available on the market; the standard for bolts has been repeatedly revised; some bolt systems have become accepted; others are no longer used; bolt failures have been analyzed; questionable bolt systems have been reviewed. With this new edition of the bolt brochure, the DAV Safety Research Department summarizes the current state of the art in the bolting.

Through this brochure and other measures, the DAV strives to provide information and guidance to increase awareness and improve safety.

- *„The Installation and Replacement of Climbing Bolts, a Declaration“ provides guidance to establish „good style“ and balanced route development so that climbing is preserved for future generations* *(see page 48)*.
- *Anyone involved in the management of climbing areas on natural rock is sometimes confronted with legal questions that can lead to uncertainty about whether their own actions are legal. The DAV Legal Commission has collected and processed the most important legal issues. They are published in the guide „The Right to Climb in Nature,“ (“Recht zum Klettern in der Natur”) to which reference is hereby made.*
- *The DAV supports rebolting activities if they are carried out with the involvement of all affected groups and in compliance with current safety knowledge as well as general and specific local/regional sports ethics standards and all environmental conservation requirements. This work requires not only a great deal of volunteer work, but also considerable financial resources in some cases. For this reason, the DAV also financially supports a baseline level of climbing area management; funding guidelines are available from the DAV.*

German Alpine Club,
Munich, 2022

Overview of bolt types

Bolts can be assigned to two „systems" according to the different principles of the anchoring of the bolt in the rock:

– Glue-in bolt systems

– Mechanical bolt systems.

Bolt systems

Fig. 1 Glue-in bolts can be recognized by the chemical bonding agent the "glue" around the bolt shaft at the entrance of the borehole)

Fig. 2 Mechanical bolts (in the picture an „express anchor") can be identified by the mechanical fastener (usually the nut or, in the case of hammer-in anchors, the hammer-in pin)

Glue-in bolts

Glue-in bolts (also known colloquially as "adhesive anchor bolts") are fixed in the borehole with a bonding agent that establishes an „adhesive bond" with the irregularities of the rock in the borehole and those on the bolt shaft.

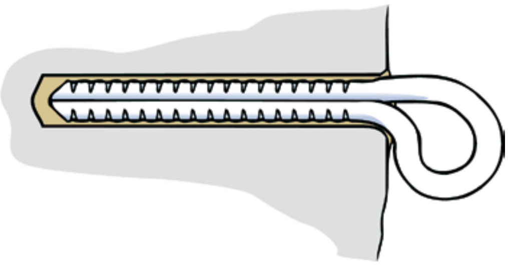


Fig. 3 In the case of glue-in bolts, the bonding agent (yellow) creates the „material or adhesive bond" necessary for strength

Mechanical bolts

Mechanical bolts are further divided into „frictional" and „positive locking" systems. While the frictionally engaged systems (also known as expansion bolts) are held in the drilled hole by an expansion pressure, the positive-locking or form-fit systems are almost free of expansion pressure. Instead, they work via a form fit, a kind of interlocking with the rock that is produced by a sleeve system or a thread.

Frictionally engaged systems („expansion anchors")

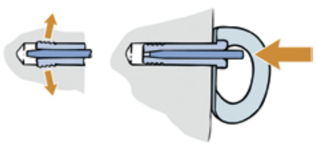


Fig. 4a Drop-in anchor

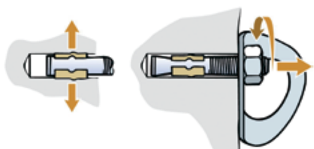


Fig. 4b wedge anchor

Positive locking systems

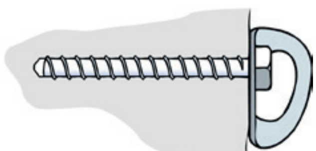


Fig. 4c Sleeve anchor

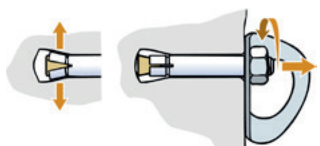


Fig. 4d Undercut anchor

Standards for bolts

Two systems of standards exist for safety-related mountaineering equipment. On the one hand, there is a European standard for rock anchors (bolts), EN 959; on the other hand, the UIAA standard for rock anchors, UIAA 123 maintained by the International Climbing and Mountaineering Federation (Union Internationale de Associations d'Alpinisme). While the EN represents a mandatory minimum standard for mountaineering equipment in Europe, the UIAA standard is usually stricter and is accepted worldwide. However, it is voluntary and does not have to be fulfilled by the manufacturers of the products.

Unlike carabiners, slings, and ropes, bolts and anchors are not classified as „personal protective equipment" (PPE) under EU regulations because bolts are not carried by the climber personally but remain installed in the rock. Thus, there is neither independent testing nor quality assurance monitoring by a certified testing authority for climbing bolts. Additionally, there is no CE mark with a four-digit test number on bolts. Manufacturers must nevertheless ensure that their products meet the requirements of the EN standard. They are responsible for compliance with the standard and quality assurance and can document the fulfillment of this obligation with a CE mark on the bolt. Many manufacturers simply mark the number of the EN standard on their product.

If a manufacturer wants to put the „UIAA" trademark on a bolt to indicate that the product also meets UIAA requirements, it must be tested for conformity with the UIAA Rock Anchors Standard, UIAA 123, in a certified testing laboratory in accordance with UIAA regulations. Either the test must be repeated annually or the manufacturer must provide certified evidence of quality control.

The main requirements of EN 959:2018 and UIAA 123:2020 for rock anchors

- The **radial strength** in standard concrete must be at least 25 kN.
- The **axial strength** in standard concrete must be at least 15 kN (UIAA: 20 kN).

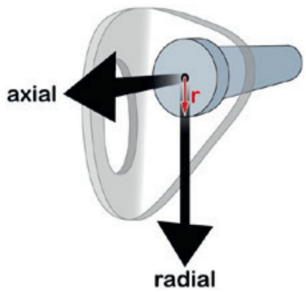


Fig. 5 Pulling directions for bolts and rock anchors

- For glue-in bolts, the **setting length** must be at least 70 mm.
- For mechanical bolts, the **setting length** must be at least five times the borehole diameter.
  Due to the expansion pressure of mechanical bolts, the DAV Safety Research Department recommends a setting depth of at least 70 mm, regardless of the diameter.

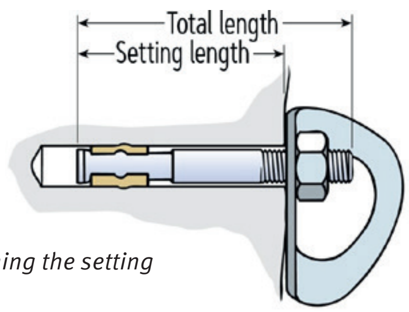


Fig. 6 Dimensioning the setting length of bolts

- For expansion anchor bolts, the expansion must be independent of the contact with the bottom of the hole **(drilling depth)**.
- All **edges of** the bolt that protrude from the rock must be rounded.
- In the case of bolts made of a combination of different materials, the individual **materials** must be selected in such a way that no galvanic corrosion (contact corrosion) occurs.
- The bolt's corrosion resistance class must be visibly marked on the bolt. In the UIAA standard, the classification of the corrosion resistance is additionally backed up with a test procedure. Chapter 4 goes into more detail about corrosion

  Since 2018 (the new edition of EN 959), bolts have been divided into three **corrosion resistance classes:**
  - Class 1 for aggressive environments where stress corrosion cracking (SCC) is expected.
  - Class 2 for outdoor areas where stress corrosion cracking is not expected and
  - Class 3 for indoor use.
- Belay anchors or link/chain constructions that connect bolts with each other are, according to standard, **„Safety anchors"**. All components of such structures must withstand a tensile force of 25 kN and be made of the same metal.
- On the bolt must be **marked:** manufacturer's name or logo, lot or serial number, bolt class, model name (if multiple models are offered by the manufacturer), and a symbol referencing the manufacturer's information.
- The UIAA additionally requires a torque test; the bolt must sustain 150 Nm torque in standard concrete for glue-in bolts, during which the bolt must not move in the borehole.

A short history of bolts

The first bolts were set in the Austrian mountains of Wilder Kaiser as early as 1944. These so-called pin bolts (also known as „Sticht“ bolts, *Fig. 7)* consist of a square shaft that has been driven into a round drill hole. They were usually not installed with the aim of creating reliable protection that can withstand a fall. First and foremost, they were used for progression in aid climbing. Therefore, they should be used with extreme skepticism. In some cases, they are only a few centimeters deep in the rock! In pull-out tests, the variability of strengths was very large (3-15 kN). Even today you can find many of these old bolts, for example in the Dolomites.

In the 1970s, the „self-drilling anchor“ *(Fig. 8)* became established and is still encountered today. This is an expansion anchor system in which a cone expands the anchor tip when the core pin is hammered in. The anchor hole is drilled by hand using the self-drilling anchor mounted on a drill. The cutting edge of the self-drilling mechanism must be made of hardened steel, so these anchors are inherently subject to corrosion! The lug and screw, on the other hand, can be made of stainless steel and give a solid impression from the outside. A time bomb is ticking here! In most cases, these anchor systems rust in the center of the anchor, as there is a moisture-collecting cavity between the end of the expansion cone and the lug screw (keyword „contact corrosion“).

When cordless hammer drills came onto the market, self-drilling anchors were often set with the help of these power drills, which creates an additional danger: if the hole is drilled too deeply with the power drill, the cone does not expand the anchor crown or does not spread it sufficiently, since it has to be in contact with the bottom of the hole. With insufficient expansion, the anchor has insufficient strength when pulled outward. This failuremechanism also plagues the old ring-bolt expansion anchors—which are still common, especially in Europe—and thus these anchors must be critically evaluated: they had to be set with a drill, as the anchor is not self-drilling, which requires particularly high precision. Due to accidents resulting from this problem, the standards for rock anchors require that the anchorage of the bolt must be independent of the depth of the borehole.

Unfortunately, these questionable bolts are not always clearly recognizable *(Fig. 12)*. For example, self-drilling ring bolts are still found and can easily be confused with modern glue-in bolt.

Fig. 7 „Sticht“ bolts from the 1950s and 1960s

Fig. 8 Examples of self-drilling anchors (a type of expansion bolt system)

Fig. 9 Contact corrosion in the cavity of a self-drilling bolt

Fig. 10 This self-drilling bolt snapped during a sport climbing fall

Fig. 11 Ring bolt expansion anchors without self-drilling bit – if the hole is drilled too deeply, the ring will be in contact with the rock before the cone at the bottom of the hole has expanded the anchor enough to sufficiently withstand axial pull

Fig. 12 Easy to confuse from the outside: on the left a glue-in, on the right an old self-drilling ring anchor. In the case of self-drilling anchors, the hole must be sealed to prevent the ingress of water and the resulting corrosion. The sealant looks like bonding agent from the outside and hides the drill bit, making the problem invisible …

Fig. 13 Second generation DAV ring bolts (CAUTION!). From the outside, this system is easily recognizable by the typical sealing compound that surrounds the anchors. Rust traces are often visible here when corrosion has started in inside. The outer diameter of these rings is 75 mm, the ring thickness is 12 mm.

Fig. 14 Third generation DAV ring bolt (unproblematic). The outer diameter of rings of this generation is only 70 mm, the ring thickness is 10 mm.

As early as the beginning of the 1970s, Pit Schubert installed the so-called „AV rings". Since then, they have been regarded as reliable anchors and are still used today, for example, as rappel anchors. However, the second of the three generations carries a risk: it is based on the self-drilling system's center pin *(Fig. 13)* and can - without this being apparent from the outside - corrode internally and then break. One such incident, in which fortunately no one was harmed, has been documented. These rings should therefore be assessed like a hammer-in bolt and, optimally, replaced—in most cases this has already been done.

At the end of the seventies, sport climbing became more and more established and climbers were looking for new ways to install reliable anchors. In the Elbe sandstone region, Oskar Bühler developed and used the Bühler bolt still in use today.

It was not until the 1980s that the first standard for bolts appeared (UIAA-123). Now the various „standard-compliant" systems have been developed. The CEN Rock Anchors Standard (EN 959) has been revised several times since then. The most important innovations of the latest revision of the standard (edition EN 959:2018) were the introduction of the three categories for corrosion resistance and the formulation of minimum requirements for „belay stance anchors".

But even after the introduction of the standard, in some places, home-made bolts continued to be manufactured and used. Thus, about 6000 so-called "Sigibolts" *(Fig. 15)* were equipped in the Hochkönig area, in the Dachstein and Tennengebirge mountains, and in the Gesäuse.

Fig. 15 Attention! The so-called "Sigibolt" is a non-standard, glue-in bolt, a "home-made" brand, which was frequently used in the Hochkönig area, in the Dachstein and Tennen mountains and in the Gesäuse until about 2006. At first sight, this type of bolt looks confidence inspiring, but due to design-related defects, its strength must be considered similar to the strength of a normal piton („hammered in piton")!

Fig. 16 The original equipment with which Oskar Bühler installed his bolts. Photo: Christl Gensthaler (née Bühler).

After a fatal accident occurred in 2005 due to the failure of a Sigibolt, the DAV Safety Research Department conducted extensive research on this type of bolt. Three problems of the bolt came to light:

1. The rapid-setting binding agent, Biber Rapid, used in many Sigibolts is not suitable for heavy-duty applications and has strengths that are too low to meet the standard requirements.
2. The sometimes insufficiently wide borehole diameter may lead to insufficient mixing of the bonding agent components in the Sigibolts installed with glass bonding agent capsules. These bolts can fail under axial load even at low forces in the range of the body weight. However, the danger is assessable, since it is those bolts that protrude far from the rock. With these, the utmost caution is required!
3. Some of the steel used was not suitable for welding. This can lead to bolt breakage at very low forces and this danger cannot be detected by inspection!

Sigibolts, however, should have been largely replaced by now. DAV safety research shows that bolts must comply with the standard, and it is imperative to refrain from using home-made anchors

Bolt study 2020

In October 2019, a climber on the Lenninger Alb discovered a crack on a bolt and was able to break it off with a simple carabiner turn test. In the Frankenjura, two anchor bolts failed in the summer and fall of 2020. In one case the bolt broke, in the other the rock in which the bolt had been installed. In one fall, the climber fell on the belayer and seriously injured the latter. The second fall ended mildly, because the last intermediate anchor was clipped and prevented groundfall. These incidents prompted the DAV Safety Research Department to conduct extensive testing in southern German sport climbing areas from May to December 2020.

The aim was to obtain an overview of the strength of questionable anchor systems in order to assess the urgency of rebolting. A total of 148 bolts were tested in eleven climbing areas: in the Bavarian foothills of the Alps, in the Blautal, on the Lenninger Alb, in the Frankenjura and in the Allgäu. In these areas, there were many bolts with design principles that had been defined as „questionable." These were 33 self-drilling bolts, 31 eye bolts with 10 and 8 mm diameters, 19 wedge anchors with 8 and 10 mm diameters and different lugs, 4 drop-in anchors, 5 ring anchors with hammer-in expansion cones, 25 homemade or DIY (do it yourself) anchors and 31 industrially manufactured glue-in bolts. Each bolt was loaded with a slowly increasing force (quasi-static tensile test) until failure or until the standard requirement (EN 959:2018) was reached - either in the axial loading direction (standard requirement 15 kN) or radially (standard requirement 25 kN). The maximum measured force and the cause of failure were recorded:

Either the connection between the bolt and the rock failed and the bolt was pulled out of the borehole, or the bolt itself broke, or the rock area around the bolt broke. Since the test is destructive, only either the radial or the axial maximum tensile force could be determined from a single bolt. Therefore, several specimens of the same bolt type were always tested in the axial and radial directions: 72 bolts in axial, 76 in radial direction.

More details on the study procedure can be found in the article Panorama 2/2021 „Achtung Aus-Reißer!"

Practical categorization of results according to the traffic color light scheme:

Category	Color	Threshold values	Meaning
1	Dark green	F≥25kN (radial) F≥15kN (axial)	The bolt sustained a tensile force above the minimum strength defined in the standards (EN 959:2018/UIAA 123).
2	Light green	25kN›F≥20kN (radial) 15kN›F≥12kN (axial)	This bolt would have held any theoretically possible fall arrest even though the breaking strength was below that specified in the CEN/UIAA standards.
3	Yellow	20kN›F≥12kN (radial) 12kN›F≥7,2kN (axial)	At the time of testing, the bolt would have sustained any fall arrest forces expected in practice. Danger looms if the bolt condition deteriorates further due to corrosion..
4	Orange	12kN›F≥5kN (radial) 7,2kN›F≥3kN (axial)	This bolt would not have withstood fall arrest forces expected in practice.
5	Red	5kN›F (radial) 3kN›F (axial)	This bolt would probably have failed during fall arrest.

Tbl. 1

A total of 117 out of 148 bolts tested (79%) fell into categories 1 and 2 and would have withstood a fall with sufficient safety. 21 (14%) of the tested bolts were assigned to category 3, i.e. would only become dangerous if the bolt condition deteriorated further, e.g. due to corrosion.

Ten (7%) of the tested bolts were classified as category 4, which means that they might have failed in the event of a very hard fall (5-12 kN—possible during normal climbing). Among the 148 bolts, none was discovered that had to be assigned to the worst category 5, i.e. would most likely have failed in the event of a fall *(Fig. 17)*.

For the bolts that might not have withstood any fall (category 4), the rock failed on half of them (1 self-drilling, 4 cemented-in glue-in anchors). On three bolts, the connection between bolt and rock failed (2 eye bolts and one bolt secured with a plastic shaft). In the case of an 8 mm express anchor and a self-drilling bolt, the bolt broke *(Fig. 18)*.

1) Total results

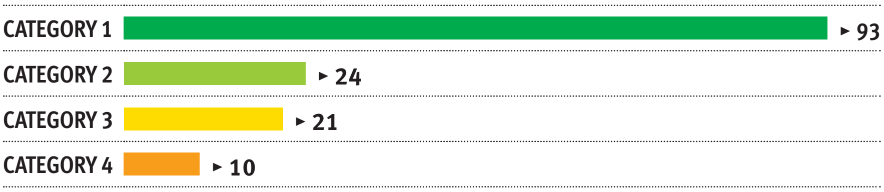


Fig. 17 Results of the 148 tested bolts sorted by the 5 categories defined above.

2) Failure pattern

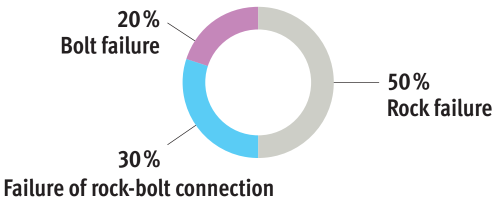


Fig. 18 Category 4 bolts (n= 10) by cause of failure

Fig. 19 Glue-in bolt from the bolt study with too little distance to the left (crack) and below to the edge. At a 6.8 kN radial load, the bolt pulled out together with the rock.

Evaluation of the study results

Bolt failures are rare events; most bolts withstand high forces. This is true even though the sample selection explicitly targeted questionable anchors. However, the previous year's incidents, as well as the results of the survey, show that individual bolts have the potential to fail.

Looking at the weak bolts, which are assigned to category 4, rock failure is the main cause. The reason for this may be a fundamentally poor local rock quality, a poor setting location (e.g. too close to a crack or edge) or an unsuitable combination of bolt system and rock quality (e.g. an express anchor in sandstone).

The second most common cause of failure of Category 4 bolts is a weak connection between the bolt and the rock. Here, this weakness can be caused either by inadequate installation technique or an unsuitable combination of anchor system and rock.

Self-drilling bolts and narrow diameter express anchors (8 mm diameter) failed at unacceptably low values and therefore have proved themselves to be unsuitable. Both systems are no longer state of the art and are now to be considered as questionable anchors. The 8 mm express anchors have an inadequate cross-section, and the expansion pressure acts too close to the rock surface. Self-drilling bolts still held in some cases during the study, but the maximum tensile forces varied considerably. Therefore, Self-drilling bolts are to be considered questionable. Due to their design, there may be a corrosion problem that is not visible from the outside, the binding depth is too shallow, and the anchoring system is dependent on the depth of the bottom of the borehole.

Prioritizing the replacement of questionable bolts

In the following, the bolt replacement priorities of the bolt systems considered in the 2020 Bolt Study are presented. **The bases for the assessment are the results of the study, the evaluation of documented incidents with these bolt systems, and construction considerations for the systems.**

Self-drilling bolts

Of the 33 self-drilling bolts tested in 2020, 61% were category 1-dark green, 21% category 2-light green, 12% category 3- yellow and 6% (2 pieces) category-4 orange. The causes of failure were: fracture of the hanger, fracture of the drill bit, pull-out of the drill bit from the borehole, and breakage of the surrounding rock.

Although the results suggest that relatively few self-drilling bolts have low failure loads, their replacement should still be considered critical. Due to their design, there may be a corrosion problem that is not visible from the outside, the binding depth is too shallow, and the anchoring system is dependent on the depth of the bottom of the borehole.

Eye bolts

Of the 31 bolts tested in 2020, 45% were category 1 - dark green, 26% category 2 - light green, 23% category 3- yellow and 6% (2 pieces) category 4 - orange. The causes of failure were: failure of the weld with subsequent bending up of the eye, breakage of the shaft at the borehole edge, pull-out of the bolt from the borehole.

In principle, the use of eye bolts as anchors for climbing does not correspond to the original purpose of eye bolts. They are approved for anchoring scaffolding to building facades and are therefore only suitable for axial tension. The hazard potential is strongly dependent on the diameter and the surrounding rock quality. The small-diameter, 8 mm, eye bolts in particular should be replaced promptly, but even the thicker ones should not be trusted unconditionally. In addition, pay attention to the corrosion condition - eye bolts are often made of galvanized steel, which can rust if the zinc coating is damaged.

Wedge bolts (galvanized bolts, aluminum hangers, home-made hangers)

Of the 19 bolts tested in 2020, 53% were category 1 - dark green, 10% category 2 - light green and 32% category 3 - yellow and 5% category 4 - orange. Express anchors in categories 3 - yellow and 4 - orange were either anchors where the aluminum hanger failed, galvanized anchors, or anchors with a diameter of only 8 mm.

Even though the tested, do-it-yourself hangers withstood high tensile forces, only bolt hangers that conform to standards and are industrially produced by a certified manufacture can be trusted. In the case of DIY production, the quality of the materials can easily fluctuate, or cracks can develop during forming. In addition: different materials of the bolt and hanger and galvanized steel in general are not suitable for outdoor use because of their susceptibility to corrosion.

Ring anchor with expansion cone (Mammut)

All five Mammut rings tested in 2020 were category 1 - dark green. However, the design weaknesses of the anchor system must also be addressed here: The anchor or shaft is relatively short (does not meet the standard requirements) and is made of galvanized steel. The nearly unavoidable damage to the zinc layer can therefore lead to corrosion. In addition, the correct functioning of the anchoring mechanism depends on the full expansion of the anchor and thus on the depth of the borehole. Both the correct expansion and the internal state of corrosion are not visible from the outside, so these bolts should be replaced.

Ring bolts

Of the 4 swing rings tested in 2020, one was category 1 - dark green, two were category 2 - light green, and one was category 3 - yellow. On the bolt classified as yellow, the ring failed at the weld at 11.7 kN. It must be assumed that bolts with lower breaking loads were also installed. Therefore, these bolts should be replaced.

Home-made bolts

Of the 9 bolts tested in 2020, six were classified as dark green, one as light green, and two as yellow.

Basically, it can be said that all these bolts were made without industrial quality assurance and therefore are not trustworthy. It is true that an experienced hobbyist can produce bolts that meet the requirements of the standard. An outsider, however, cannot determine who manufactured these bolts, under which production parameters, or from which material. Due to this uncertainty, such bolts should be replaced.

Drop-in bolts

Drop-in anchors or impact anchors are still occasionally used today. The four impact anchors tested in 2020 were all category 1 - dark green. The short setting length of many of these bolts is their weak point, which is why they should be viewed critically in less-solid or surface-weathered rock.

Summary

Table 2 summarizes the rebolting priority assessment of the most commonly found questionable anchor systems in Germany. The classification is derived from the evaluation of documented incidents involving these anchor systems, construction considerations, and the results of the 2020 study. The priorities indicated (1 = very high; 2 = high; 3 = medium; 4 = low) are to be understood as a rough guide. On-site conditions such as poor rock quality or environmental conditions conducive to corrosion can greatly increase the rebolting priority.

Fig. 20 Self-drilling bolt from the DAV safety research pull-out tests

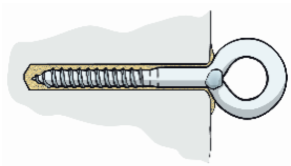
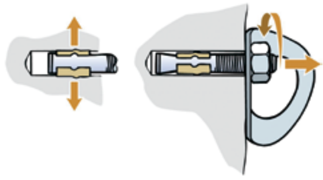
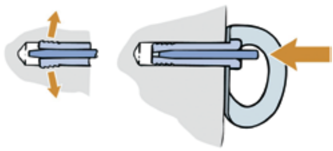
Fig. 21 Eye bolt from the DAV safety research pull-out tests

Fig. 22 8 mm wedge bolt with home-made hanger

Fig. 23 Drop-in bolt with expansioncone in DAV safety research pull-out tests

Fig. 24 Mammut ring in the DAV safety research pull-out tests

Rebolting priority of anchor systems

Bolt type	**Rebolting priority**	**Comments**
Self-drilling bolts 	1-2	**basically priority 2 rises to priority 1 if:** • soft and/or fragile rock • visible corrosion • a lack of borehole sealing • a permanently humid environment
Eye bolts 	1-3	**basically priority 3 rises to priority 1 if:** • soft rock • a hole diameter (d) ≤ 10 mm • visible traces of corrosion **rises to priority 2 if there is both:** • soft rock • a hole diameter d ≤ 10 mm
Wedge bolt galvanized 	2-4	**basically priority 4 rises to priority 2 if:** • d ‹ 10 mm • Corrosion is detectable • The bolt hanger is made of aluminum (even when it has been industrially produced) • The hanger is home-made (even if it is made of steel or stainless steel) • The threads protrude a long way past the nut (regardless
Drop-in bolt 	4	• depending on setting length, possibly compliant with standards; if possible, discuss with bolter • the setting length is critical in poor rock due to the shallow embedment depth
„Mammut Ring“ 	1-2	**basically priority 2 rises to priority 1 if:** • The rock is soft and/or fragile. • Corrosion is evident. • The ring is fixed in place.

Tbl. 2 Rebolting Priorities: 1 = very high; 2 = high; 3 = medium; 4 = low

Glue-in bolts

Glue-in bonding agents can be dispensed either in the form of cartridges or glass capsules. When setting glue-in bolts, it should be noted that all bonding agents known to the DAV Safety Research Department that are suitable for bolts are irritating or even corrosive. Therefore, when setting glue-in bolts, it is recommended to wear gloves and protective goggles.

Installing glue-in bolts

Choice of bonding agent and bolt

Not all bonding agents available on the market are suitable for axial tension. Please be sure to observe the instructions for use and the technical data sheet regarding the proper handling and use limitations of the bonding agent.

A decisive point in the choice of bonding agent for a particular application is the working temperature. Working and curing times of bonding agents depend directly on the temperature conditions at the installation site. The warmer it is, the shorter the working time of a bonding agent. On a south-facing wall, it can be so short in summer that the bonding agent begins to harden during the installation process. Especially in the case of glass bonding agent capsules, where the setting process takes more time, there is a risk at high temperatures that the bonding agent sets before the bolt is fully sunk into the hole. A bonding agent matched for warm temperatures may tend to leak out of the hole in overhangs at low temperatures. If the bonding agent is very runny, there is also a risk that the bolt will sag in the borehole and therefore the thickness of the bonding agent will not be even on all sides. There are therefore special winter bonding agents that can even be used at temperatures below freezing point. The working time of bonding agents as a function of the installation temperature is always specified in the instructions for use—another reason why the instructions must be followed!

It is also important to observe the expiration date and the storage temperature! Bonding agent that is too old or stored too warm will no longer cure!

There are also important points to consider when choosing a bolt. The shorter a glue-in bolt is, the lower the strengths that can be achieved with it. The setting length of glue-in bolts—that is, the length of the shaft that is anchored in the rock—must be at least 70 mm according to the standard. For soft rock (e.g. sandstone), significantly larger embedded depths are required (100-300 mm). Glue-in bolts with a biaxial bolt shaft (see picture on page 16,bolt below) have advantages over those with a single-axis bolt shaft (see picture on page 16, bolt above). Due to frequent rotational loading, e.g. caused by falls when working out a crux to the side of a bolt, single-axis glue-in bolts can be loosened. As soon as a glue-in bolt can be moved even minimally in the borehole, it is no longer safe!

Fig. 25 Glass bonding agent capsules - a single-shaft, glue-in bolt is shown for size comparison.

When using **glass bonding agent capsules** *(Fig. 25)*, it is important that the bolt length, drill hole depth, drill diameter and cartridge length and diameter match (Follow the manufacturers recommendations!). In fact, glass bonding agent capsules contain a defined amount of two-component bonding agent. If the material quantity for the combination of bolt and borehole is too small, the entire bolt shaft will not be surrounded by bonding agent in the borehole. If the quantity is too large (e.g. because the borehole is not wide enough or the bolt is too thick), one of the two components may run out of the borehole and the bonding agent may not cure completely because the mixing ratio of the components is not correct. Glass bonding agent capsules are not suitable for soft rock, as they widen the borehole when they are driven in.

For installing individual bolts glass bonding agent capsules are suitable. If several bolts are to be installed at once (e.g. for rebolting projects), cartridge bonding agent is a much more favorable alternative (see also p. 16: pull-out tests on different glues).

With **cartridge bonding agents**, it is important that the bonding agent, squeeze gun and mixing nozzle match! There are bonding agent cartridges that must be squeezed with two pistons and only one piston, or there are bag containers that must be squeezed in a special sleeve. In short, the manufacturer‘s recommendation must always be followed! In most cases, the manufacturer‘s own squeezing device in combination with the correct mixing nozzle must be used.

Fig. 26 Cartridge bonding agent: Bonding agent, squeeze gun and mixing nozzle must match!

There are clear differences regarding the container sizes. From some manufacturers there are also small cartridges available suitable for setting only a few bolts. Apart from special restrictions imposed by the manufacturer, cartridge bonding agents are suitable in principle for all types of stone.

„Homemade“ bolts should not be used; instead, only install bolts that conform to standards—in the outdoor area, depending on how corrosion-resistant the environment is in classes 1 and 2 *(Tbl. 5, page 31)*.

Overview lists for the selection of suitable bonding agents and the compatibility of current bolts with available glass bonding agent capsules (as of 2018) can be found in the appendix of this brochure.

Drilling

Drilling is done perpendicular to the rock surface—this ensures optimal force application to the rock and achieves the highest strength.

The borehole diameter depends on the maximum shaft diameter of the bolt. If the manufacturer provides information on drill hole depth and diameter in the instructions for use, these must be heeded. When using glass bonding agent capsules, it is essential to follow the instructions for use of the capsule-bolt, capsule, and borehole dimensions must match exactly!

Otherwise, the following guide values for bolt diameters of 8-12 mm apply when using cartridge bonding agent:

- **Drill hole diameter** = maximum shaft diameter + 1.5-2 mm (The bonding agent must be able to flow around the shaft when the bolt is installed—the annular gap between the bolt shaft and the borehole wall is necessary for this).
- **Drill hole depth** = setting length + 5 mm
  First insert the bolt into the drilled hole and check that the depth is sufficient and that the eye is in contact with the wall.

The bolt hanger or eye must be in full contact with the rock so that no additional leverage is applied to the bolt shaft. In the case of glue-in bolts, the bending radius of the bolt eye may have to be taken into account. Use the tip of the hammer to make a small indentation at the bottom of the borehole so that the bolt eye rests completely on the rock surface or is slightly embedded, to prevent the bolt from twisting *(Fig. 27)*. Make sure that the eye is still big enough to guarantee adequate distance between the rock and the clipped carabiner.

Fig. 27 Countersinking of the lower edge of the borehole with a hammer for optimal bolt placement depending on the bending radius of the glue-in bolt.

Cleaning the borehole

The bonding agent interlocks with asperities in the borehole wall. If the asperities are filled with drilling dust, the bonding agent cannot establish the bond between the bolt and the rock, but instead only bonds the drilling dust to the bolt.

Fig. 28 If the borehole is not cleaned, the bolt will only bond with the drilling dust, but not with the borehole wall. It can then be extracted along with the bonding agent at relatively low forces.

Use a round brush and a blower to clean the borehole. A synthetic brush is recommended for sandstone. A wire brush would expand the hole diameter. For limestone and harder rocks, steel brushes provide optimum results. The following procedure has proven successful:

1. Blow out the borehole with the blower
2. Brush out the borehole with the round brush (it is sufficient to push the brush in once as far as it will go and pull it out again)
3. Blow out the borehole again with the blower.
4. Repeat steps 2. and 3. twice, i.e. perform these actions three times in total

Filling the borehole

Glass bonding agent capsules are first held vertically so that the glue-in mass can flow downward and an air bubble forms at the upper (flat) end of the capsule. Make sure that the bonding agent flows viscously. In this way, it can be checked whether the bonding agent is still usable. If nothing flows in the glass capsule (even before the expiry date!), it can no longer be used!

The glass bonding agent capsule is then inserted into the borehole with the round end first until the capsule is in contact with the back of the hole. The cartridge is then destroyed with a hammer blow to the glue-in bolt placed on the end of the glass capsule. Attention: the entire contents of the cartridge must remain in the borehole, nothing must be lost—otherwise the mixing ratio will no longer be correct!

With the **cartridge bonding agents**, the borehole is filled from the bottom to about two-thirds height. For this purpose, the mixing nozzle is pushed all the way into the borehole and slowly pulled out as the bonding agent is applied. This ensures that no air bubble forms.

It is very important that the pre-flow is discarded in case of newly opened cartridges or when using a new mixing nozzle, as the mixing ratio is not correct at the beginning. The bonding agent manufacturer will provide more detailed information in the installation instructions.

Fig. 29a Brushing and ...

Fig. 29b ... blowing out: three times in alternation

Installing the bolt

When setting a bolt with a glass bonding agent capsule, the bolt is screwed in with a setting tool and percussion drill or, alternatively, hammered in centimeter by centimeter with a hammer or mallet while constantly rotating around its own axis. Alternate beating and turning is important because it breaks the glass of the cartridge and mixes the different components to achieve the highest possible strength.

Attention! There are glass bonding agent capsules that may only be set with a special setting tool according to the manufacturer‘s information, as otherwise there is no guarantee that the resin and hardener will be mixed. The cartridges tested and presented here are also suitable in principle for setting by hand according to the method shown. Whether the bonding agent has bonded or not is shown by the obligatory final check: only when the carabiner rotation test shows that the bolt is anchored immovably in the borehole may the bolt be used for climbing (see section „Check“).

It is easier to set the bolts with the cartridge bonding agents: the bolt is simply pressed into the hole slowly by hand.

Finalizing the installation

Finally, the bolt must be aligned in its optimum position according to the expected force application. Smooth out the excess bonding agent, which— if set correctly—will leak a little from the drill hole, with a spatula (not with the fingers, as the bonding agent is usually corrosive and, in the case of glass bonding agent capsules, may contain glass splinters!).

The temperature-dependent curing time of the bonding agent must be observed in accordance with the product information. The bolt must not be moved or loaded during the curing time!

Quality inspection

For quality control purposes, each glue-in bolt installation must be checked after the curing time. This is the only way to detect „failures“ caused by bonding agents that have not set correctly. The check can be carried out by applying a small torsional load, as glue-in anchors are most sensitive to this failure mode. For this test, a carabiner is twisted in the bolt (exerting a small torque) and an attempt is made to turn the bolt by hand. If the bolt can be moved in this way, the bonding agent has not set properly: the strength is insufficient!

Fig. 31 Carabiner rotation test to check whether the bonding agent has set correctly. Attention: do not apply more torque with a larger lever. If more torque is used, a good bond may be destroyed under certain circumstances!

Fig. 30 The bonding agent that has leaked out from the annular gap between the bolt and the rock is smoothed out.

Fig. 32 If good bolts are set in solid rock with the right bonding agent, then they are reliable anchors. Improperly installed glue-in bolts are a life-threatening trap. Climbing was done on the bolts shown here—they could be pulled out by hand! A final inspection would have revealed the danger sooner!

Pull-out tests on glue-in bonding agents

To obtain information on the performance of the glue-in bonding agents currently available on the market in natural stone, the DAV Safety Research Department carried out the tests documented here. The bonding agents tested were selected based on criteria relevant to climbing.

Criteria for bonding agent selection

The following criteria were considered in the selection of bonding agents for the tests:

- **Approval for heavy-duty applications**
  Only so-called "high-performance bonding agents" should be used in climbing applications.
- **Approval for uncracked concrete**
  The properties of uncracked concrete are comparable to those of solid natural stone.
- **Processing and curing time**
  Bonding agents based on vinyl ester or methacrylate have shorter curing times than bonding agents based on epoxy resin. Both long and short times have specific advantages and disadvantages for different areas of use in climbing.
- **Suitability for water-filled boreholes**
  Not all bonding agents tested are also suitable for wet conditions—however, for some climbing applications (e.g. ice climbing, canyoning) this can be an important criterion when deciding which bonding agent to use!
- **Suitability for overhead installation**
  … for placements in overhangs and roofs.
- **Installation temperature**
  Installation and curing times depend on the ambient temperature and must be suitable for the situation.

A total of eleven injection mortars (= cartridge bonding agents) and five glass bonding agent capsules from different manufacturers were selected and tested based on these criteria. The aim was to check whether bolts set in natural stone with these bonding agents also achieve the axial pull-out forces required by the standard for bolts.

Test arrangement

Since the strength achieved by a glue-in anchor depends primarily on the embedment depth, extra short glue-in anchors were selected for the tests. The cartridge bonding agents were tested with a glue-in anchor from Austrialpin. This bolt has a diameter of 12 mm and, with a length of 75 mm, is only minimally above the minimum setting length of 70 mm required by the standard for glue-in bolts.

Since not all selected glass bonding agent capsules from the various manufacturers are available in a suitable length for this bolt, a glue-in bolt from Raumer was used to test the glass bonding agent capsules (diameter: 8 mm; length: 80 mm). Thus, all glass bonding agent capsules selected according to the criteria described above could also be tested under the same conditions.

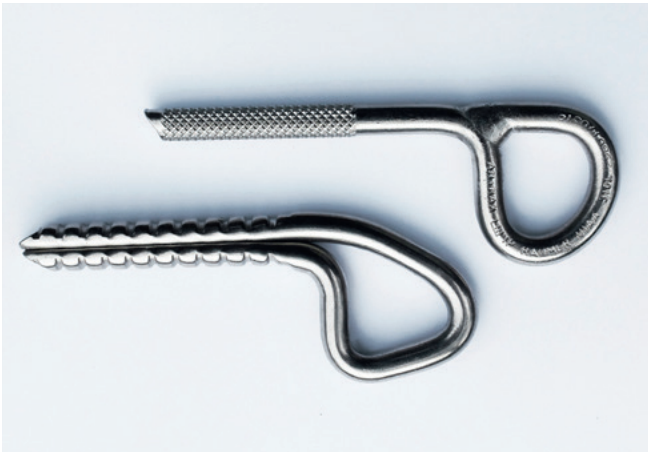


Fig. 33 The glue-in bolt from the manufacturer Raumer (top single-axis, shaft length 80 mm, diameter 8 mm) was used for the pull-out tests of the glass bonding agent capsules, while the cartridge bonding agent was tested with the bolt from the manufacturer AustriAlpin (bottom double-axis, shaft length 75 mm, diameter 12 mm).

Three bolts per bolt agent were set in granite, limestone, and sandstone. The following table *(Tbl. 3)* contains the properties of the selected rock types. All bolts were set correctly and loaded axially, in the direction of the borehole.

Properties of rock types

	Red Main Sandstone (Eichenbühl)	**Limestone** (Gohare Beige)	**Granite** (Hinterthiessen)
Density [kg/dm^3]	2,22 – 2,27	2,85	2,63
Compressive strength [N/mm^2]	79 – 107	97,09	219,3
Bending tensile strength [N/mm^2]	7,1 – 9,3	13,02	17,6

Tbl. 3 The properties of the rock types selected for the experiments (cf. Börner and Hill: www.abraxas-stone-experts.com)

Fig. 34 Axial pull-out tests: left limestone, right granite.

Overview of the tested bonding agents

Fig. 35 **Bonding agent capsules**

- Fischer RSB
- Mungo MVA
- MKT V-P
- Würth W-VD
- Upat UKA 3*

* *since shortly after the completion of the tests, the Upat UKA 3 Plus has replaced the older Upat UKA 3. According to information from the manufacturer, the performance has been increased.*

Fig. 36 **Cartridge bonding agents**

- Hilti HIT-HY 200-A
- Hilti Hit-RE 500 V3
- Fischer FIS V
- Fischer Green
- Upat UPM 55
- Upat UPM 44
- Würth WIT-VM 250
- Würth WIT-Nordic
- MKT VMU Plus
- Bossong V Plus
- Bossong Epoxy 21

Results of the pull-out tests

Three bolts were set and pulled out for each rock and bonding agent. The bar in the diagram *(Fig. 35-38)* indicates the average pull-out force determined for each bonding agent in kN. Pull-out tests with water (blue bars) were only carried out with bonding agents that are also approved by the manufacturer for this application.

In the tests in sandstone, in almost all cases the rock failed before the bond failed. The pull-out values therefore do not provide any information on the holding force of the glue-in bonding agent and are therefore not shown here (for more details on bolts in soft rock, see chapter 2.3).

Some of the bonding agents have resisted extraction with marked stubbornness. In these cases, the tests had to be stopped at 50 kN (~ 5000 kg) to preserve the extractor. The crossbar marks the minimum requirement of the EN 959 standard for anchors in axial tension (15 kN ~ 1500 kg). All the cartridge bonding agents tested delivered values above the standard requirement of 15 kN, and in dry boreholes well above this.

Results for cartridge bonding agents

(Tested with the bolt of the manufacturer AustriAlpin: 75 mm length, 12 mm diameter)

Axial pull-out values limestone

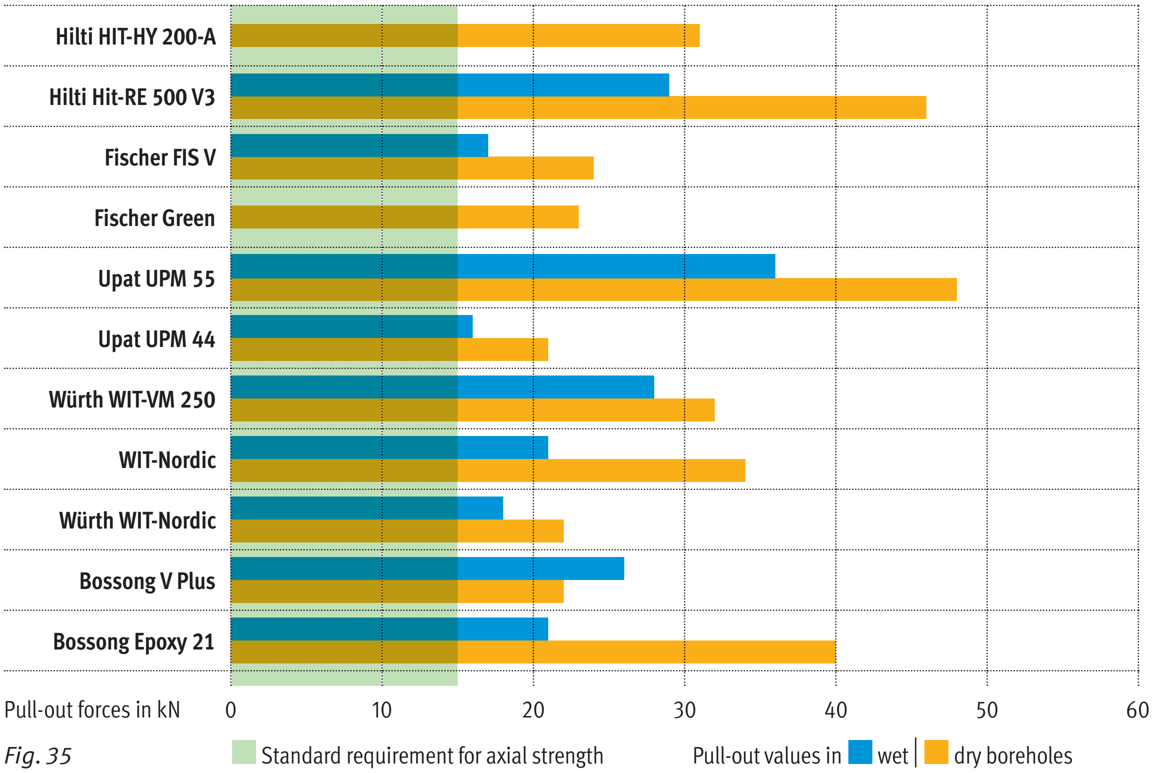


Fig. 35

Axial pull-out values granite

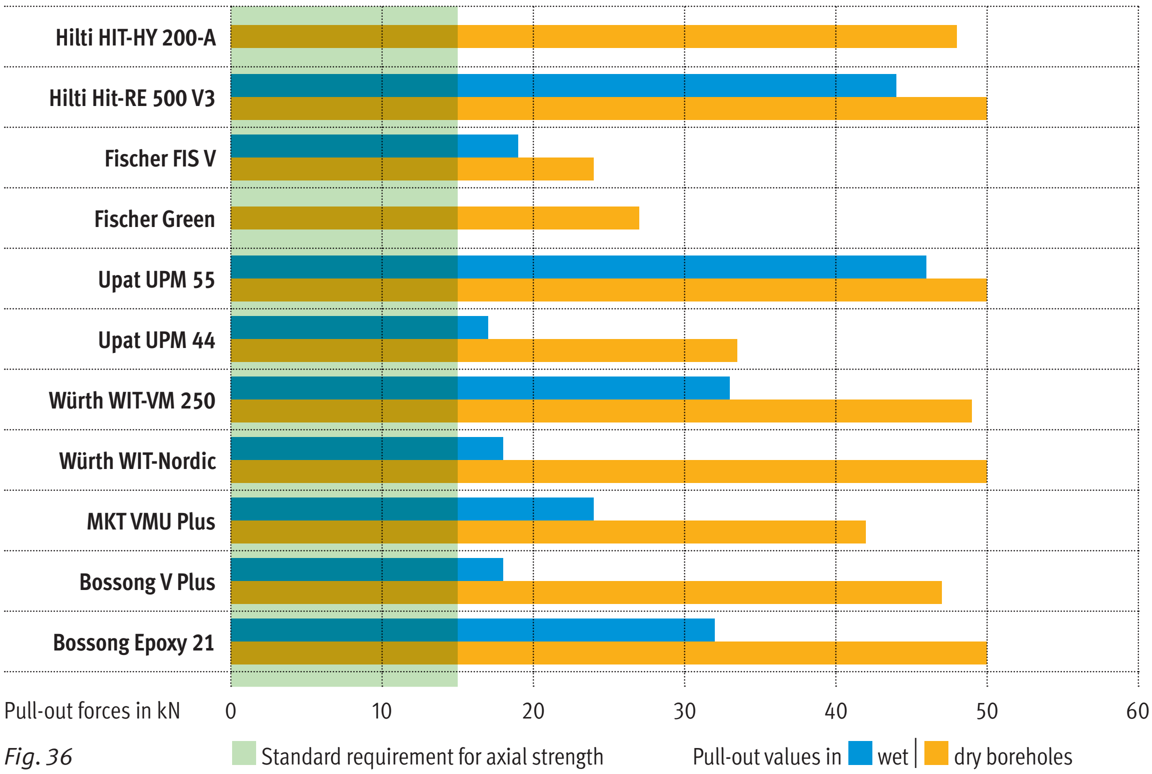


Fig. 36

Results for glass bonding agent capsules

(Tested with the bolt of the manufacturer Raumer: 80 mm length, 8 mm diameter)

Axial pull-out values limestone

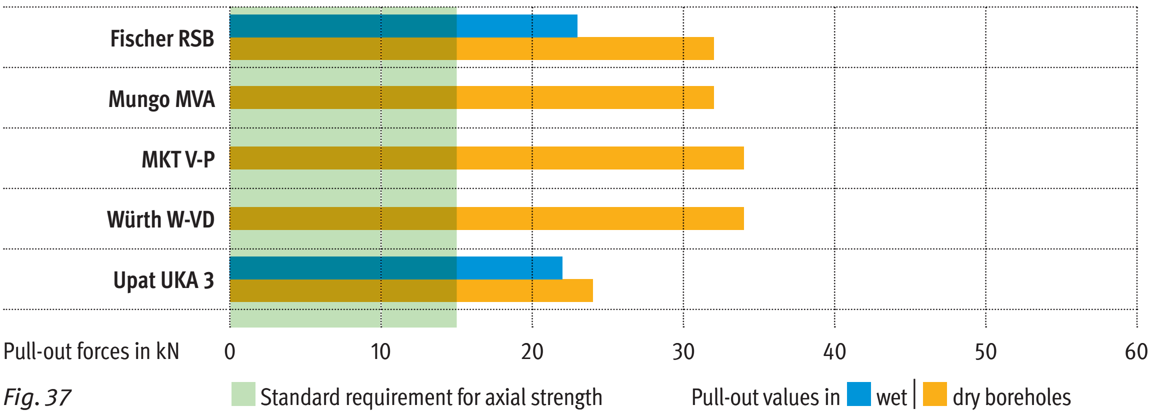


Fig. 37

Axiale Auszugswerte Granit

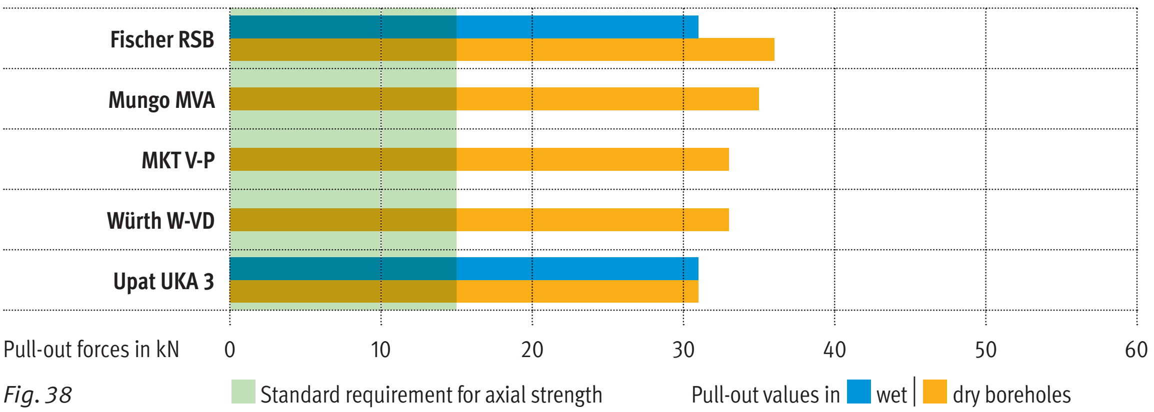


Fig. 38

In all dry borehole tests, Raumer's 8mm bolt failed in the glass bonding agent capsule tests, not the bond between the bolt and rock. In all tests with results above 30 kN, the bonding agent would have sustained even higher pullout strengths. All tested glass bonding agent capsules delivered values far above the standard requirement of 15 kN.

Glue-in bolts in hard and medium-hard rock

In summary, it can be stated that all bonding agents selected according to the above criteria (see page 16) for glue-in bolts in limestone and granite provided values above the standard requirement. It is concluded that bonding agents approved for heavy-duty use and suitable for natural stone are generally suitable for glue-in bolts in solid rock unless otherwise stated in the manufacturer's specifications.

Glue-in bolts in soft rock

Glue-in bolts transfer applied force to the surrounding rock. The softer this is, the greater the risk that the rock will not withstand an application of force and will fail along with the bolt.

Fig. 39 During the pull-out tests in the red Main sandstone, the soft rock gave way. The rock around the bolt was pulled out of the wall like a cork.

In climbing areas with relatively soft rock (e.g. sandstone of the Elbe Sandstone Mountains), the question of sufficient bolt dimensioning is most significant; the softer the rock, the more massive the bolts must be *(Fig. 40)*!

Glass bonding agent capsules are not suitable in principle in softer sandstone. The glass splinters expand the borehole diameter when the bolt is screwed in and due to the low density of the rock, bonding agent components escape into the surrounding rock. The high heat storage capacity of the rock also shortens the installation time too much at warm temperatures. For shaft lengths necessary in particularly soft sandstone (e.g. Elbe Sandstone Mountains), glass bonding agent capsules are not available anyway. However, there are harder sandstone varieties (sandstone consolidated by cementation with silica or metamorphically transformed sandstone) for which glass bonding agent capsules may be appropriate.

Fig. 40 Dimensions of glue-in bolts: above, a special bolt for the soft sandstone in the Elbe Sandstone Mountains; below, the bolt models for solid rock used for the DAV Safety Research tests

Checklist for glue-in bolts

Bolt

- ☑ Shaft length at least 70 mm - longer for soft rocks (e.g. sandstone)!
- ☑ thread-like, ribbed surface, in no case smooth! Threaded rods are not optimal, they can be turned out with little effort.
- ☑ In outdoor areas, use only bolts of the bolt classes 1 and 2*, in corrosion-friendly environments (e.g. near the ocean, swimming pools, or busy roads) use only bolts of class 1!
  **since the revision of EN 959, there are three classes of bolts (see "Standard requirements" in chapter 1.2)*
- ☑ do not use home-made bolts. Manual welding can lead to embrittlement of the steel sufficient to allow fractures at body weight.

Glue-in bonding agent

- ☑ approved for heavy duty use
- ☑ Observe expiration date and correct storage (cool)
- ☑ suitable dispenser and mixing nozzle for cartridge
- ☑ discard bonding agent pre-flow for cartridge dispensing
- ☑ For glass bonding agent capsules: Match cartridge, borehole depth, and bolt!
- ☑ Gloves and goggles are recommended when working with irritating or corrosive bonding agent
- ☑ Heed the installation temperature limits.
- ☑ Choose a bonding agent with a reasonable installation and curing time

Rock

- ☑ compact
- ☑ the distance of the borehole from edges, cracks and holes must be at least 15 cm.

Borehole

- ☑ drill perpendicular (90°) to the rock surface
- ☑ thorough cleaning (3x brushing and blowing)
- ☑ length and diameter of the drill bit suitable for the bolt (and for the glass bonding agent capsule used, see instructions for use)
- ☑ as dry as possible; wet only with bonding agent that is also suitable for this purpose according to the manufacturer

Always

- ☑ Make a final check by carabiner rotation test (after curing time has elapsed)!

Mechanical bolts

Mechanical anchor systems have the great advantage that they can be loaded immediately after installation. This makes it the favored system for first ascents from below. The assembly is usually simple. Express anchors in particular are very cost-effective compared with glue-in bolts.

As with glue-in anchors, only systems from the corrosion resistance class (class 1)—if corrosion is expected—or from class 2 (no corrosion is expected) are suitable for outdoor use. With mechanical bolts, the borehole is not sealed which can cause an invisible corrosion problem due to water penetration if the steel quality is unsuitable.

Because of their shallow bolting depth, friction locking systems are not recommended for soft rock.

Friction locking systems

Express anchors

The express anchor (also known as a heavy-duty anchor) is the most widely used mechanical bolt system. Cost and ease of assembly speak in favor of this system. There is a certain danger in “overwinding” the nut. The permissible torque must be observed according to the setting instructions. For climbing, anchors with diameter of 10 mm (length approx. 75 mm, torque between 20 and 35 Nm) and 12 mm (length approx. 85 mm, torque between 40 and 50 Nm) make sense. One disadvantage of the express anchors is that sometimes the nut loosens and then must be retightened. If the nut is seated on the anchor with too few turns, then it can be “torn from the threads.”

Fig. 41 Express anchor

Drop-in and hammer-in bolts

The drop-in and hammer-in anchors (also called nail anchor or “Long-Life™ Bolt”) work very simply in their application. Apart from a drill and hammer, no additional tools are required. Clear disadvantages are the small setting depth in connection with a very high expansion pressure near the rock surface. For these reasons, they are only suitable for hard rock such as granite.

Fig. 42 Drop-in anchor

Positive locking systems

Screw anchors

Screw anchors (also called concrete screws) work very simply. According to the screw shaft, a relatively thin hole is drilled. Then the screw is twisted into the hole. In the process, the tip of the screw cuts a thread into the rock, similar to an ice screw in ice. The system is free of expansion pressure. The bolt is immediately loadable.

The disadvantage is the high insertion resistance and that the anchor loosens easily over time. The system only works in medium-hard rocks such as limestone.

Fig. 43 Screw anchor with lug

In harder rock types such as gneiss or granite, the screw anchor cannot be used, as the insertion resistance is too high and the screw may break off or be damaged during insertion. Therefore, according to the setting instructions, a torque of 40 Nm (for Multi Monti Screw (MMS)-10 anchors) and 55 Nm (for MMS-12 anchors) must be observed. In soft rock (e.g. sandstone), the strength of the screw in the rock is insufficient, since the form fit between the thread and the rock does not provide the necessary axial pull-out values.

Both an advantage and disadvantage is the fact that the system can be removed without any problems—an advantage because after screw bolt installation, it can easily be replaced with glue-in bolts etc. A disadvantage because the screw bolts can be easily unscrewed by hand after a few falls or slowly unscrew themselves under load. The screw anchors are therefore very suitable as temporary anchors—when unscrewed, only the drill hole remains.

In principle, screw-in anchors with an outer diameter of MMS 10 mm (8 mm drill hole, length 85 mm) and MMS 12 mm (10 mm drill hole, length 100 mm) are suitable as bolts.

Sleeve bolts/Undercut anchors

Since sleeve bolts/undercut anchors have not become established due to their complicated installation and high price, we will refrain from describing the system in more detail at this point. In principle, undercut anchors are nevertheless suitable as bolts.

Pull-out tests on mechanical bolts

Test arrangement

Five test samples per bolt type were pulled out in limestone and the mean values determined. As with the glue-in bolts, the pull-out was carried out in the axial direction of pull to compare the values of the mechanical bolts with those of the glue-in bolts. In addition, possible weaknesses of the expansion anchor systems would become apparent under such loading.

The drop-in bolts was tested (since it is commercially available) with an embedment depth of 45 mm and a diameter of 12 mm. This bolt type therefore does not comply with the new bolt standard (length 5 x drill hole diameter)!

For the wedge bolts, diameters of 10 and 12 mm were tested. The embedment depths were 75 mm for M10 (10 mm diameter) anchors and 85 mm for M12 (12 mm diameter). The screw anchors were tested with outer diameters MMS 10 mm (borehole diameter 8 mm) with an 85 mm length and MMS 12 mm (borehole diameter 10 mm) with a 100 mm length.

Results

Figure 44 shows the pull-out strength results for the mechanical bolt systems.

All tested mechanical systems showed sufficient to very good strengths in limestone. Specifically, the following causes of system failure occurred:

- In the case of the wedge bolts, the expansion ring was pulled over the cone in some tests (a non-problematic material failure).
- With the wedge bolts, it was possible to pull directly on the thread until the bolt failed (a non-problematic material failure).
- The drop-in bolts (Long Life) deformed and pulled out of the borehole, sometimes in conjunction with rock failure. The insufficient embedment depth is the main reason for the relatively weak strengths.
- The hangers on the screw anchors tore off. Therefore, there was no difference in strength between the different diameters of MMS 10 and MMS 12.

Axial pull-out forces of mechanical bolts Limestone

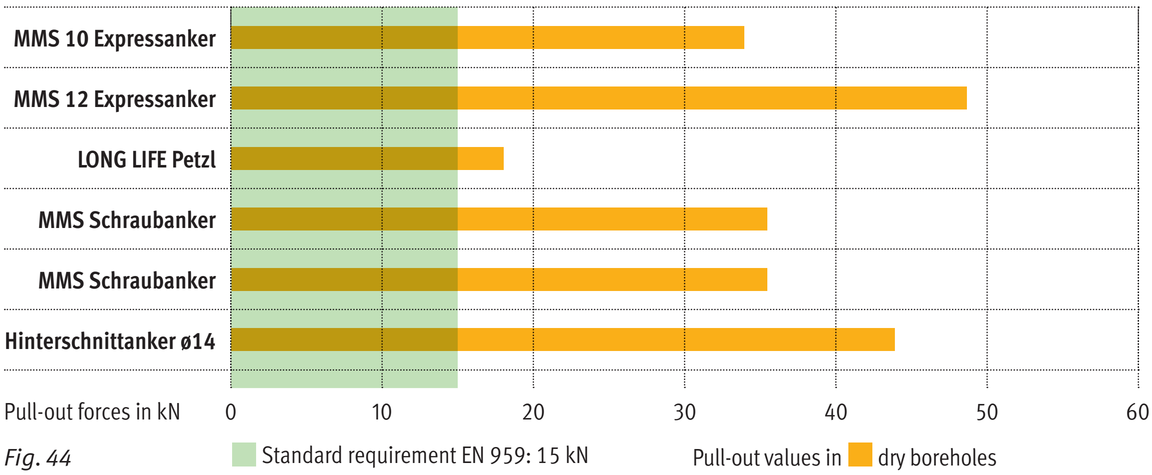


Fig. 44

Installing mechanical bolts

Drilling and cleaning the borehole

The borehole diameter is between 8 and 12 mm, depending on the bolt. For drop-in and wedge bolts, the hole is drilled with a diameter corresponding to the outer diameter of the anchor, i.e. for M10 express anchors with 10 mm.
The hole for screw bolts is drilled according to the diameter of the anchor (without the external thread), i.e. 8 mm for the MMS 10 (see instructions for use). For drop-in bolts, the hole is drilled slightly deeper than the setting length. For express anchors, it is recommended to drill the hole a little deeper than the anchor length to be able to "plunge" the anchor—in case the bolt has been placed incorrectly or if rebolting is carried out at a later date—with a hammer into the rock. When drilling, it is important that the drill hole is not "worn out" by repeated "back and forth" movements or by lateral offset of the drill. Finally, the correct drill hole diameter is critical for optimal expansion of the anchor.

It is imperative that the rock is solid, as the expansion pressure from the anchor system on the rock acts in addition to the fall load, especially in the case of friction-locked systems. It is therefore also particularly important to comply with the center-to-center and edge distances.

The distance of the drill hole from edges, cracks and holes must not be less than 15 cm. When using long bolts in soft rock, the radius around the bolt is increased to three times the embedment depth. The center distance between two bolts (to be observed especially in belay and rappel anchors with two bolts) should be 30 cm (a 15 cm radius of „sacred rock" around each bolt).

Although borehole cleaning for mechanical bolts is less important than with glue-ins, blowing out the drilling dust is recommended to ensure optimum functioning of the expansion system.

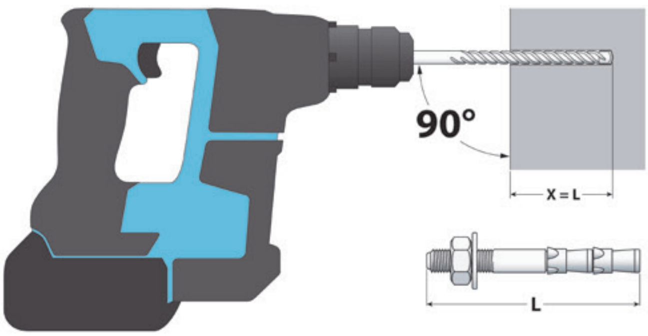


Fig. 45 The hole is drilled 90° to the rock surface and, in the case of the express anchor, at a depth corresponding to the anchor length or a few millimeters deeper.

Fig. 46a This bolt was set only a few centimeters from obvious cracks and weak points in the rock.

Fig. 46b The bolt broke at 5 kN. This force can occur during a sport climbing fall.

Installing the bolt

Wedge bolt

Express anchors are equipped with a nut and hanger and driven into the drilled hole so that the anchor is not accidentally positioned too deeply to be tightened. Do not strike the nut, as this could damage the thread and make tightening impossible.

The spreading effect is achieved by tightening the nut. Caution is advised here. If an express anchor is overtightened, it is immediately damaged. Therefore, manufacturers specify a torque with which the anchors must be installed. Depending on the steel alloy and the diameter, this is between 20 and 60 Nm.

Fig. 47 For wedge anchors, it is essential to observe the maximum torque (between 25 and 45 Nm for M10 according to manufacturer's specifications). The anchor should protrude slightly above the screw (approx. 3-5 mm) after reaching the tightening torque.

When the tightening torque specified by the manufacturer is reached, the anchor should protrude slightly above the nut. If an express anchor does not extend when the nut is tightened, the drill hole is too large, or you have drilled into a cavity. This does not guarantee sufficient strength for axial loads. Caution should be exercised when the nut abuts on the end of the thread. One could get the impression that the sleeve would now spread as the mounting resistance increases. This assembly error can be recognized by a thread protruding far (over 1 cm) beyond the nut.

The use of a torque wrench is optimal. Since almost no first ascentionist carries a heavy torque wrench along—especially when bolting a route on lead—more conscientious work must be done here. A short open-end wrench with a small lever arm is better than a long one, and experience in applying torque is necessary when working with open-end wrenches. The sleeve must spread but must not be overtightened. As a reference value: With a 20 cm long open-end wrench, a maximum torque of 45 Nm was generated in tests among climbers.

Screw bolt

Screw anchors cut a thread in the rock. For this purpose, the drill hole must have the correct diameter (MMS 10 -> 8 mm, MMS 12 -> 10 mm). The hole must be deep enough and blown out. Otherwise, you push the drilling dust into the drill hole when screwing it in, and the tip of the bolt is prematurely at the end of the drill hole. Do not exceed the specified torque when setting (observe manufacturer's instructions and use a torque wrench!). Otherwise, this could lead to damage to the screw, which could then possibly break when subjected to a fall load. Therefore, screw anchors are only suitable for medium-hard rocks such as limestone. Already with the somewhat harder dolomite, the twist-in resistance is borderline!

Fig. 47 Even with screw anchors, the maximum torque must be adhered to according to the manufacturer's specifications.

Drop-in bolt

The drop-in anchor is inserted into the drilled hole and then the expansion pin is driven in with the hammer. This can be tedious and requires some skill, as the hanger should not be hit. Otherwise, the system is very easy to assemble. Because of the shallow setting depth, drop-in anchors are only suitable for very strong and compact rock.

Expansion pressure

Expansion anchor systems, i.e. wedge bolts and drop-in bolts, must exert a certain expansion pressure on the surrounding rock, otherwise they would not hold axially. The expansion pressure is more favorable the deeper it is induced in the rock. This means - especially with less compact rock: the greater the anchor length, the better. It should be noted that anchor length, embedment depth and expansion pressure depth differ depending on the anchor design.

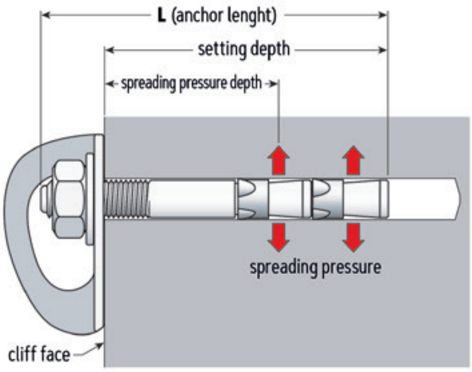


Fig. 48 Wedge bolts with double cones apply the expansion pressure to the rock in two places, but closer to the rock surface. The spreading pressure depth is significantly shorter than the anchor length. With an 85 mm long anchor of this design, the first expansion pressure acts about 40 mm below the rock surface.

The standard requires an embedment depth of five times the borehole diameter for mechanical bolts. In soft rocks such as sandstone or brittle limestone, much greater embedment depths of between 100 and 300 mm are required, or glue-in bolts make much more sense. The DAV Safety Research Department recommends a minimum embedment depth of 70 mm for all bolt systems.

Cyclic loading

To investigate the influence of frequent falls on strength, DAV Safety Research Department has carried out a series of cyclic loading tests.

Three M10 express anchors (MKT BZ plus), MMS 10 screw anchors (HECO) and MMS 12 screw anchors (HECO) were each tested. All bolt systems were set in a limestone slab. The anchors were loaded with 5000 load cycles between 1 kN and 7 kN. The force application as well as the final strength test were carried out in both axial and radial directions.

Results

Table 4 shows the average breaking loads of the three tests under axial and radial load application after 5000 load cycles between 1 and 7 kN.

Average breaking load

	after axial load	after radial load
M10 Expressanker	35,3 kN	32,8 kN
MMS 10 Schraubanker	43,3 kN	19,1 kN*
MMS 12 Schraubanker	76,9 kN	47,6 kN

Tbl. 4 ** In one of the three tests, the MMS 10 screw anchor only withstood a breaking load of of 11.8 kN. For the other anchors, all values were well above the norm and the scatter was much smaller.*

5000 load cycles—i.e. simulated falls—on a bolt correspond to an extreme loading condition that is hardly to be expected in practice. The MMS 12 screw anchor and the M10 express anchor survived this testing with a clear reserve relative to the standard requirement of 15 kN. The two systems are therefore suitable for routes in which frequent falls are to be expected. In one case, the MMS 10 screw anchor only withstood a breaking load of 11.8 kN after loading and is thus below the required strength according to the standard. The MMS 10 screw anchor should not be used for routes where very frequent falls are expected.

The actual diameter of the M10 express anchor is 8.2 mm at the thread and 7.8 mm at the base of the expansion cone. The MMS 10 screw anchor is only 7.8 mm thick throughout. Even smaller material cross sections (M8) do not provide sufficient strengths for practical use.

Checklist for mechanical bolt systems

Bolts

☑ Embedment length at least five times the borehole diameter (corresponds to an anchor length of 50 mm for M10); the DAV Safety Research Department generally recommends at least 70 mm embedment length.

☑ Sufficient dimensioning (shaft diameter at least 10 mm, or M10).

☑ Corrosion-resistant components (A4—316—or HCR steel), no galvanized components (see the standard requirements and Table 5).

Rock

☑ Compact, medium-hard to hard rock. In soft rock use glue-in bolts with sufficient length!

☑ Distance of the borehole to edges, cracks, and holes at least 15 cm. When using long bolts in soft rock, the radius around the bolt is increased to three times the embedment depth.

Borehole

☑ Do not „drill out“ the borehole by moving the drilling machine back and forth.

☑ Blow out borehole.

☑ Drill deep enough; otherwise the bolt will stick out too far and there will be no optimum spreading effect. In addition, the bolt should be countersunk if necessary.

Mounting

☑ Heed torque limitations.

Fig. 49 Photo: Helmut Mittermayr

Bolt corrosion

Bolts are exposed to the weather and are therefore subject to the risk of corrosion. Corrosion in the context of bolts means the chemical decomposition of steel by oxidation in the presence of water.

Corrosion and corrosion protection

Water from the humidity in the air or from precipitation in general, together with oxygen from the surrounding air, allows electrochemical processes to take place that decompose the steel and form corrosion products, the rust. These iron oxides (more precisely: iron hydroxides) are present as a sponge-like layer, which means that water is adsorbed. At the same time, this layer tends to flake off. Thus, when exposed to weathering, rusting and rusting through is an inevitable process. Air pollutants or salty atmospheres can significantly accelerate these electrochemical processes.

Corrosion protection is achieved by shielding the steel from the environment, in the simplest case by painting or coating (e.g. galvanizing). With both measures, however, there is a slight risk of injury to the protective layer.

If the steel contains larger amounts of chromium, an extremely thin but dense and firmly adhering chromium oxide layer forms on the surface of the steel part. This protective layer prevents further corrosion against oxygen and water; this is referred to as passivation. Injuries to the passivation layer can heal on their own. Such chromium-containing, corrosion-resistant steels are in principle suitable as bolt materials.

Fig. 50a/b An anchor chain as manufactured (left) and after a few months on the rock (right). Rings and chain links were made of a corrosion-resistant steel with about 18% chromium content, the bolts shown were accidentally made of a normal mild steel.

Types of corrosion

Contact corrosion/galvanic corrosion

Contact corrosion is known from old bolts, whose drill anchor, expansion cone, screw and lug were made of different metals. Under moist conditions electrochemical processes (like those in a battery) occur, resulting in the decomposition of the less noble material. All components of a bolt and accordingly belay/rappel anchor construction must therefore be made of the same material.

Intergranular corrosion

The protective chromium oxide layer can only form if the chromium atoms are dissolved in the iron matrix and can move freely and not if the chromium is firmly bound in precipitates (analogy from everyday life: sugar can contribute to the sweetness of coffee only when it is dissolved, not when it settles to the bottom of the cup). Whether the chromium is dissolved and can thus have a protective effect depends on the temperature control during the manufacture of the semi-finished product or bolt (analogy: stirring the coffee). The manufacturer therefore bears a high level of responsibility; the end user cannot detect a faulty microstructure in the bolt. Corrosion due to insufficiently dissolved chromium does not always occur over a large area and in a conspicuous manner; often the attack takes place very locally with the formation of a fine crack (the crack then runs along the boundaries of the grain structure of the steel, hence the term intergranular corrosion).

A potential weak point is at the welds of bolts, rings and chain links exposed to weathering. Unfavorable cooling conditions after welding cause chromium to bind in precipitates, so the steel loses its corrosion resistance locally. This could be counteracted by subsequent, targeted heat treatment, which is often omitted for cost reasons. It is recommended to check welded constructions regularly.

Fig. 51 A bolt system incorrectly heat-treated during manufacture two days after setting in a subtropical climbing area by the sea.

Fig. 52 A crack caused by intergranular corrosion in the heat-affected zone of the welded joint of a chain link of an anchor..

Stress corrosion cracking

Stress corrosion cracking (SCC) can proceed along the grain boundaries of the steel like intergranular corrosion, but the mechanism is completely different. In the case of intergranular corrosion, an unfavorable microstructure of the steel is present. For SSC to occur requires three conditions simultaneously. The first is a material that is susceptible to SCC, even with a normal microstructure. Unfortunately, many of the steels used for bolts belong to this group of susceptible materials. A second condition is the exposure to a corrosion-promoting medium, in particular aqueous solutions containing chloride ions. The third condition is the presence of tensile or shear stresses, which can also be present without external loading due to residual stresses in the material from the manufacturing process.

The knowledge about stress corrosion cracking has been gained mainly in the context of industrial chemical processes, the conditions prevailing there (acting media, temperatures, etc.) make it difficult to transfer the findings to the situation in climbing areas. The UIAA has therefore initiated the first peer-reviewed studies on stress corrosion cracking of bolts under typical environmental conditions. To date, the DAV Safety Research Department is not aware of any case of anchor damage clearly attributed to SCC in a climbing area in the German-speaking parts of Europe. In tropical, marine climbing areas, however, stress corrosion cracking is the main damage mechanism.

Pitting corrosion and crevice corrosion

Pitting corrosion and crevice corrosion are closely related phenomenologically. In the absence of oxygen and the simultaneous presence of chloride ions, etc., damage to the passivation layer cannot heal; on the contrary, electrochemical reactions occur between the noble passivation layer and the less noble substrate, the steel. Pitting corrosion is referred to when the damage to the passivation layer has "natural" causes, and crevice corrosion when there are structural causes (e.g. under washers and bolt heads). The susceptibility of a steel to pitting and crevice corrosion can be estimated from its chemical composition.

Summary

- Contact corrosion: This is not a problem with standard bolt systems, as all components must be made of the same material.
- Intergranular corrosion: Not a problem with error-free, manufactured, standard-compliant systems. Cases of damage due to defective welds are documented, and regular weld inspections are therefore recommended.
- SCC and crevice corrosion: can be prevented by appropriate material selection.

Material selection

The standard defines three classes of application conditions and identifies some materials to be considered *(Tbl. 5)*. The classification of the steels obviously follows the susceptibility to crevice corrosion with the motivation to prevent the insidious SCC.

- Class 3 is intended for indoor use and requires only low corrosion protection; however, it is important to note that in gyms near industrial areas, swimming pools with chlorinated water, or the sea, use of Class 2 or 1 bolts may be necessary.
- Class 2 includes outdoor applications in areas with moderate corrosion, an environment conducive to stress corrosion cracking is not present. For the Alps and most Central European sport climbing areas, this class should be sufficient. The steels proposed for this class are exclusively material with classification numbers 1.44xx (in Europe, A4 steel and, in the US, 316 steel are within the 1.44xx series), i.e. chromium steels with molybdenum additions, as molybdenum supports passivation against strongly oxidizing salt solutions. The steels with classification numbers 1.43xx (in Europe, A2 steel and, in the US, 304 steel are within the 1.43xx series) which have proven their worth are not included. In climbing areas close to industrial or metropolitan areas, corrosion processes can be promoted by air pollution, and the defined steels provide a safety buffer.
- Class 1 is intended for applications in highly corrosive environments, i.e., coastal, nearshore (ocean winds can carry significant salt concentrations far inland), extreme air pollution, or unfavorable rock types. "Titanium grade 2", which is listed in this class, is far superior to the steels in terms of corrosion resistance and could also be assigned to its own class. It is often the only permanent solution for tropical climbing areas directly by the sea.

Bolt classes and characteristics

Klasse	Umgebung	Werkstoffe
1	Outdoor (aggressive corrosion-promoting environment enabling stress corrosion cracking: high chloride concentration in the atmosphere, temperatures above 30 °C, humidity 20 to 70 %; sea salt and/or other salts e.g. due to karst rock and/or acidic environment)	3.7035 (Titanium grade 2) 1.4565 (X2CrNiMnMoNbN25-18-5-4) 1.4529 (X1NiCrMoCuN25-20-7) 1.4547 (X1CrNiMoCuN20-18-7) 1.4539 (X1CrNiMoCu25-20-5)
2	Outdoor (no stress corrosion cracking to be expected)	1.4401 (X5CrNiMo 17-12-2) 1.4404 (X2CrNiMo 17-12-2) 1.4435 (X2CrNiMo 18-14-3) The previously widely used steels 1.4301 (X5CrNi18-10) and 1.4306 (X2CrNi18-10) are expressly not recommended for outdoor use.
3	Indoor (no stress corrosion cracking expected; in gyms near industrial areas, swimming pools or the sea, the use of Class 2 or Class 1 bolts may be necessary.)	no specifications (low protection against corrosion, e.g. electroplating on sheet metal, anodizing on aluminum alloy)

Tbl. 5 *Source: DIN EN 959:2019-04*

What the standard cannot do is specifically assign the environmental class to a particular climbing area. In many cases, the situation will be clear-cut; in some cases, there will be a need for rebolting.

Vigilance against corrosion is advisable. Despite the requirements of the current standard, corrosion can occasionally occur due to:

- Misjudgment of the environmental class: e.g. unexpected influence of air pollution.
- Misjudgment of the corrosion resistance of the material: There is no test procedure that represents the typical environmental conditions of real climbing areas. There are no specifications as to how manufacturers should rank the resistance to stress corrosion cracking for a material not on the list.
- Defective welds: based on experience with relevant damage cases, intergranular corrosion in the heat-affected zone of welds cannot be ruled out. This is not a fundamental problem, but a problem of individual manufacturers or batches.

Fig. 53 Bolt fracture in marine environment. The steel used was not able to withstand the corrosive influences and broke under simple rappelling loads.

Rock

The best bolt only holds as much as the rock in which it is set! However, with regard to the factors of density and strength, rock types differ significantly. This has an influence on the type of anchoring technique chosen for installation.

However, classifying rocks according to their „strength" is difficult to impossible. The following should provide a little insight into the diversity of a small selection of rock types. For the sake of simplicity, we divide them into soft, medium-hard, and hard rocks in this brochure.

Rock types

Geologists classify rocks into 3 main groups based on their formation:

- Sedimentary rocks: In the water or on land, loose rock material is initially deposited, which solidifies over long periods of time due to a binding agent. Sedimentary rocks can be divided into three subgroups according to their formation and composition. There are sediments that consist only of (mechanical) fragments of other rocks, for example sandstone, they are called clastic sediments (from the Greek klastós = broken). In addition, sediments can be formed by chemical means (for example, salt or gypsum). Or the starting material is of biogenic origin. Limestone and dolomite, for example, formed from the calcareous shells of small and tiny marine organisms. There are very soft sedimentary rocks that are still suitable for climbing, such as the Saxon Elbe Sandstone. Specially made long anchors must be used here. Harder sediments, such as compact limestone, are also suitable for standard bolts.
- Igneous rocks are formed by the solidification of molten rock. The molten and hot magma rises due to the density difference in the Earth's mantle and penetrates or displaces surrounding rock layers. If it reaches the surface in a volcanic eruption and solidifies rapidly, it is called volcanic. In the formation of granite, on the other hand, acidic magma gets stuck in a chamber in the Earth's crust and crystallizes there over a long period of time, forming medium-sized crystals. Basalt is the basic counterpart to this, fine-grained due to cooling quickly. Igneous rocks belong to the hard rocks.
- The collective term metamorphic rocks refers to rocks that have been transformed by the effects of heat and pressure deep in the Earth's mantle. Countless different products can be created from different source rocks at different temperatures and pressures. As frequent representatives, Gneiss, slate, and marble are to be named.

In German climbing areas we find mainly sedimentary rock of medium density and strength. But there are also areas where magmatic and metamorphic rocks are climbed. Some of the rocks occurring in Germany with their respective special features are explained in more detail in the following by way of example.

Fig. 54 Typical rock with pockets in the Fränkischen Schweiz region

Examples of different rock types in Germany

Igneous rocks in the Black Forest

In the Black Forest, climbing is mainly done on igneous rock, porphyry and granite, i.e. on predominantly hard to very hard rocks. The peculiarities of the different types of porphyry are especially important for the installation of bolts.

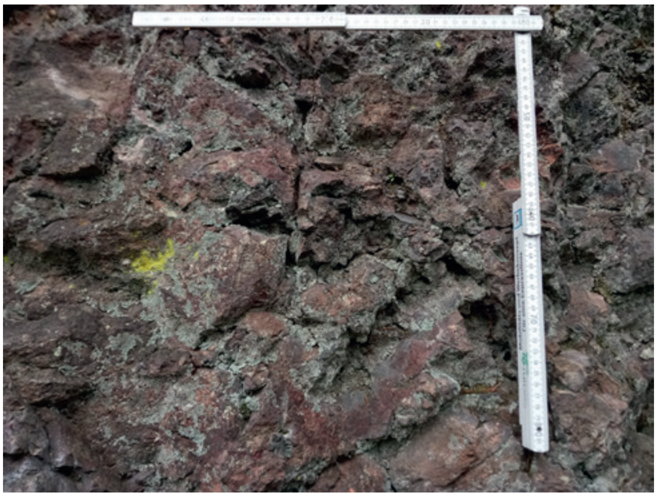


Fig. 55 The finely structured porphyry at Lägerfelsen in the Triberg district is hard, but cavities are repeatedly encountered during drilling. That is why it makes sense to use glue-in bolts there in particular. The cavities can be filled with cartridge bonding agent. Glass bonding agent capsules are not suitable here because of the cavities.

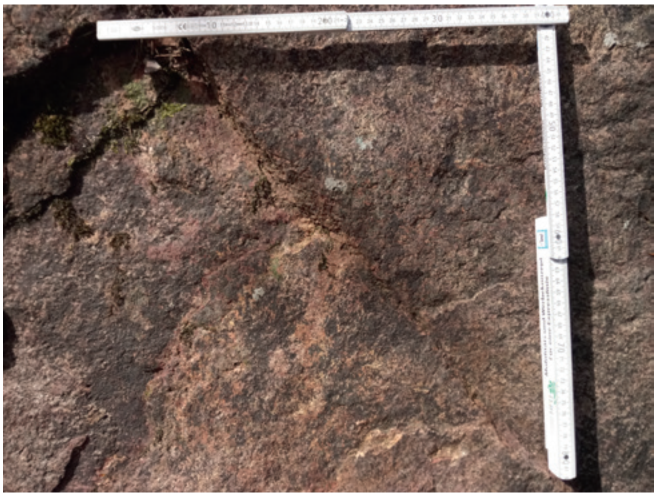


Fig. 56 The rock in the lower area at the Swimming Pool Rock (a former quarry) is a slate-like porphyry. Due to the risk that the compressive effect of the heavy-duty anchors could have a detrimental effect on the slate-like structures of the porphyry here, the crag was equipped exclusively with glue-in bolts.

Quartzite in Hunsrück

Quartzites are metamorphically altered quartz-rich rocks, such as sandstone. The picture was taken in the "Oberhauser Felsen" crag near Kirn (in the Kirner Dolomites).

Fig. 57 Quartzite in Hunsrück

The very fractured quartzite proves to be relatively difficult to work with here during drilling, and the rock is very hard. If you hit one of the white, pure quartz inclusions with the drill, the drill is usually broken afterwards. The main difficulty for setting bolts here is the large-scale rock quality: Due to the many cracks, it is important to thoroughly tap percussively to hear whether the rock is sound before setting a bolt.

The rocks of the Kirner Dolomites are in the working area of the Kaiserslautern Section of the Alpine Club. All the old bolts here have been replaced by glue-in bolts in recent years. New routes should only be developed here after consultation with the section's area supervisors!

Fig. 58 Glue-in bolts in Palatinate sandstone.

Palatinate sandstone

By definition, sandstone consists of the sediment sand, i.e. quartz grains, which are held together by a binder (silicic acid and calcium carbonate). Regarding grain sizes and the strength of the binding forces, there are large differences from area to area. Although the Palatinate sandstone is harder than the Elbe sandstone, the properties of the rock place similarly high demands on the bolting and rebolting of climbing routes. Sandstone is generally less solid than most of the other types of rock suitable for climbing. Therefore, it requires

particularly experienced bolters in assessing the rock quality. For example, one should have a feeling for the drilling resistance to be expected during drilling to be able to distinguish "good" from "rotten" rock. When setting bolts, it is also important to consider the direction in which the bolt will exert force on the surrounding rock.

Sometimes, due to the low hardness of the rock, the "responsible rock wardens" use glue-in bolts with shaft lengths sometimes far in excess of 20 cm. Local peculiarities usually make a second bolt at the top anchor superfluous here. Drill holes must be cleaned particularly thoroughly to ensure the bond between the bonding agent and the borehole wall. Moisture in the borehole must be considered even more critically than in other rocks. There are also particularities in the choice of the right bonding agent and its handling.

Bolting activities in the Palatinate must be discussed with the responsible rock warden, not only because of the peculiarities of the rock, but especially because of special regulations concerning environmental conservation!

Fig. 59 Typical „failure cone" of a glue-in anchor in sandstone that was determined to be too short during an investigation by the DAV Safety Research Department

Gneiss and granite in the Bavarian Forest

In the Bavarian Forest one climbs mainly on gneiss and granite, which are both very hard rocks. In granite, crystals are always visible to the naked eye; in gneiss often. These similarities are probably why climbers like to confuse them. They are often colloquially referred to by the term “primeval rock” However, the two types of rock are fundamentally different. Granite is igneous rock and consists mainly of feldspar, quartz, and mica. Gneiss, on the other hand, is metamorphic rock. Its components vary greatly. As a rule, both rocks are very strong, which is why all types of bolts are suitable here in principle.

Fig. 60 Fine-grained granite in Viechtach. It is easy to see how „chaotically“ the crystals are distributed. Photo: Christian Hartl.

Fig. 61 In contrast to granite, the crystal structure of gneiss (the picture shows the rock on the Kaitersberg in the Upper Palatinate) always contains a recognizable „direction.“ The „order“ between the crystals comes from the pressure during the transformation processes during metamorphosis. Photo: Christian Hartl.

Limestone in the Fränkischen Schweiz

The limestone of the Fränkischen Schweiz is, compared to that of other regions, relatively soft and has some peculiarities.
Air pockets are relatively common in the rock interior and are immediately noticeable when drilling. Optimally, a new bolt position is then found in solid rock nearby. Another problem in many Franconian limestone areas is a very soft, quite moist rock layer only a few centimeters below the rock surface. The experienced bolter will notice this immediately when drilling, but the inexperienced bolter is unlikely to notice. Bolt systems which work by expansion loosen here over time, which is why glue-in bolts are used almost exclusively in the Frankenjura . To achieve sufficiently high strengths, relatively long shaft lengths must be selected in many places. It is also essential to ensure sufficient distance from edges—especially in the direction of the expected load. In soft rock, 15 cm is not sufficient to meet the standard requirement of 25 kN in axial tension, which is why a distance of three times the bolting depth is recommended here.

Fig. 62 This loosened drop-in anchor is evidence of the softer rock layers that are often found only a few centimeters below the rock surface in the Frankenjura.
For this reason, glue-in anchors are used almost exclusively. Photo: Jürgen Kollert.

Fig. 63 Typical Bühler bolt (glue-in bolt) in the Frankenjura. Photo: Jürgen Kollert.

Sandstone in the Elbe Sandstone Mountains

The peculiarities of the sandstone in the Elbe Sandstone Mountains (Sächsische Schweiz) have already been the subject of this publication several times. Due to the softness of the rock, special rules apply here, which are not dealt with in this bolt brochure. Nevertheless, a few of the Elbe sandstone peculiarities should be briefly introduced so that the reader understands why the contents of this brochure do not apply in the Elbe sandstone.

The first sporting ascent of a rock in the Sächsische Schweiz was the ascent of a rock chimney at the Königstein Fortress by the chimney sweep Abratzky in 1848. The first ascent of a free-standing peak—the Falkenstein—followed in 1864 by the Schandau gymnasts. On August 2, 1905, Rudolf Fehrmann installed the first belay ring (ring bolt) in the Sächsische Schweiz at the Großer Wehlturm. Since then, more than 23,000 of these belay rings have been installed in the more than 1,100 free-standing climbing crags.

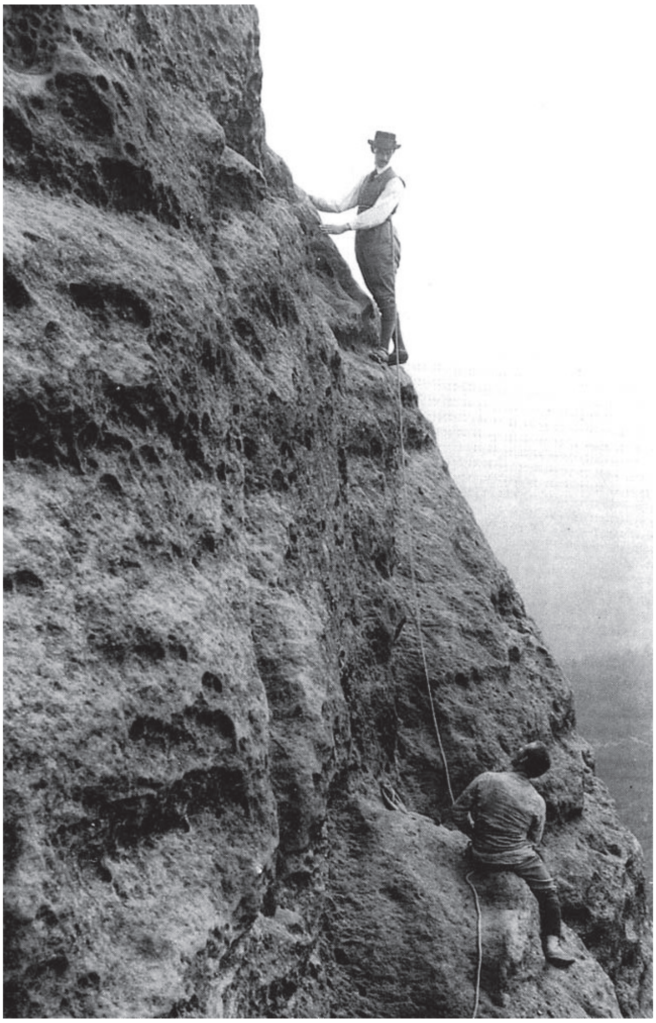


Fig. 64 Rudolf Fehrmann, the installer of the first belay ring in the Elbe Sandstone Mountains, here climbing the Winkler Tower. Photo: Archive Sächsischer Bergsteigerbund

The very soft sandstone requires much greater dimensioning of anchors than is necessary in other rocks. For this purpose, a special standard, the KTA (Die Klettertechnische Abteilung) standard, was developed for the Elbe sandstone climbing areas (the Sächsische Schweiz and the Zittau Mountains). The KTA standard specifies a diameter of 22 mm and a shaft length of 200 mm.

Fig. 65 On the left a modern Elbe stainless steel ring, on the right a KTA iron ring, in between two undersized and therefore removed old rings. Photo: Wido Woicik

The routes in the Elbe sandstone climbing areas are generally bolted starting from the ground. To ensure that climbing can continue immediately at the newly set belay point, they are not glued but traditionally "leaded." For this purpose, the drilled ring hole is lined with lead strips and the ring shaft is driven in with a hammer. Thus, it is a very specialized expansion bolt.

On some peaks, first ascents are regulated for environmental conservation reasons. Therefore, it is necessary to obtain appropriate information before carrying out a first ascent—e.g. from the Sächsischen Bergsteigerbund, the DAV Zittau Section, or other local mountaineering clubs.

The KTA is responsible for rebolting or replacing the fixed anchors in the Elbe sandstone climbing areas. In the Sächsische Schweiz, the Sächsischen Bergsteigerbund has supported the volunteer KTA for many years with full-time staff.

When replacing worn belay rings in the Elbe sandstone climbing areas, only stress-free, glue-in bolts are used. In recent years, some first ascenders have also used "glued" rings. For this purpose, temporary expansion bolts are set during the first ascent, which must be replaced with standard-compliant material after the first ascent. However, this procedure, which is quite costly for the first ascender, has not yet become generally accepted.

Due to tradition and soft rock structures, the rules for climbing Elbe sandstone stipulate that toprope climbing be done only in exceptional circumstances. For this reason, chains and quick links are not installed in the Sächsische Schweiz. The approximately 1200 rappel bolts are not designed as toprope anchor points but are intended only for abseiling and bringing up the second and are positioned accordingly.

Intermediate anchors have been installed on many sub-peaks and at other key points. These are intended for belaying the second up only and must not be used for rappelling under any circumstances to protect the rock surface.

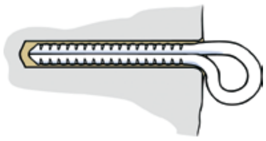
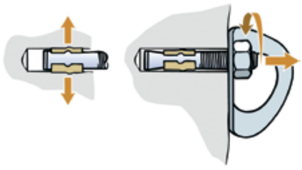
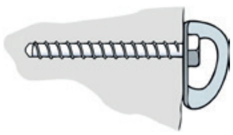
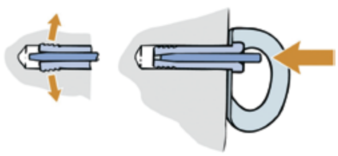
Fig. 66 Installation of iron ring by means of lead strip

Fig. 67 Rock „sawn away" by topropes and faulty rope guidance at the Rabentürmchen in the Sächsische Schweiz—an indication of the soft consistency of the rock and the importance of compliance with local rules!

General overview

The key points of the chapters on glue-in bolts, mechanical bolts, and rock are compiled here to provide an overview.

Advantages and disadvantages of the bolt systems

	Advantages	Disadvantages
glue-in anchor 	– the borehole is sealed, therefore no hidden corrosion – free of expansion pressure – high strength – suitable for all rock hardnesses	– not immediately loadable – complicated installation, susceptible to bolting errors – final inspection necessary – large borehole Ø necessary – quite expensive
Wedge anchor 	– easy to set – inexpensive – small borehole Ø – immediately loadable	– high expansion pressure – borehole not sealed – the torque must be heeded
screw anchor 	– almost free of expansion pressure – inexpensive – immediately loadable – small borehole Ø (low battery consumption).	– large insertion resistance – only suitable for limestone – borehole not sealed – may loosen – the torque must be heeded – suitable especially for temporary application
drop-in anchor 	– very easy to set – immediately loadable	– high expansion pressure – borehole not sealed – quite expensive – low embedding depth

Tbl. 6

Frequent falls *= more than 100 falls on the anchor per year to be expected (e.g. bolt at crux in Massone/Arco)*

Infrequent falls *= less than 100 falls on the anchor per year to be expected (e.g. bolt in the Danube valley or alpine sport climbing route)*

Which bolt system is suitable where?

	soft rock (sandstone)	medium-hard rock (limestone, dolomite)	hard rock (gneiss, granite, basalt)
frequent falling	– glue-in bolt, at least 100 mm, or significantly longer	– wedge bolt and screw anchor MMS12 – glue-in bolt	– wedge bolt M12 – glue-in bolt
infrequent falling	– glue-in bolt, 100 mm and longer	– wedge bolt M10 – screw anchor MMS10 – glue-in bolt	– wedge bolt M10 – glue-in bolt

Tbl. 7

Frequent falls *= more than 100 falls on the anchor per year to be expected (e.g. bolt at crux in Massone/Arco)*
Infrequent falls *= less than 100 falls on the anchor per year to be expected (e.g. bolt in the Danube valley or alpine sport climbing route)*

Fig. 68 Glue-in bolt

Placing bolts

With the help of the preceding general overview, the suitable system can be selected for a bolting or rebolting operation.

Finally, on site, the decision must be made according to the correct placement of each bolt. The rock quality plays a decisive role here. Because even the best bolt only holds as much as the rock in which it is installed—so the rock must be compact.

During an initial visual inspection, special attention is therefore paid to ...

... the **rock quality:** are there prominent cracks or similar weak points in the rock? Where is a particularly compact and even spot in the wall?

... the **suitability of the bolt's positioning for the climber to clip** and where the rope runs **(rope friction, rock edges**)

Fig. 69 collection of different bolts

Rock quality

After this initial visual inspection, it is best to tap the rock with a hammer to make sure there are no voids or cracks in it. When tapping, you can hear whether the rock is solid (high, bright sound), or whether it is "hollow" (dull sound). If you put a hand on the rock surface while tapping and feel the blow of the hammer transmitted to your hand, this is a sign that the rock is not solid.

Fig. 70a Important: before drilling, the rock is tapped. The sound reveals where the rock is solid and without cavities. Only here can a bolt be reliable. If you feel the vibrations of the hammer blows in the hand placed on the rock surface, the rock is not solid at this point.

Since an installed bolt transmits forces to the surrounding rock, the distance between the drill hole and edges and cracks should not be less than 15 cm (»equals« 2 x the setting depth for standard bolts). Because bolts that break out due to questionable rock strength often leave a funnel-shaped crater, the breakout of a bolt can cause loss of strength in the surrounding rock. To ensure that the breakout of a bolt does not have a negative effect on a bolt placed next to it, the distance between the axes of the two bolts of a top anchor or a belay station should therefore be 30 cm in the case of medium-hard rock (15 cm radius per bolt). In soft rock, the radius around the bolt is increased to three times the setting depth (10 cm embedding depth then results in 60 cm distance between two bolts). In the case of particularly strong rock and when using expansion pressure-free glue-in anchors, the basic rule "15 cm radius per bolt" can also be relaxed.

Fig. 70b An unfavorably placed bolt.

Fig. 70c After the pull-out test - the rock broke at 6 kN, far below the standard requirement for radial load of 25 kN.

Bolt position

Before drilling is finally started, it is still necessary to ensure that the placement does not induce any unfavorable **buckling load** on the carabiner.

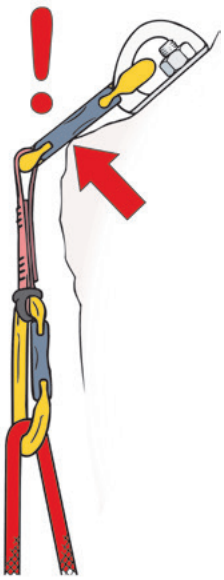


Fig. 71 This poorly placed bolt induces a buckling load on the carabiner.

High **rope friction** means high forces at the anchor and increased risk of injury for the climber and should therefore be avoided as far as possible by skillful positioning of the bolts.

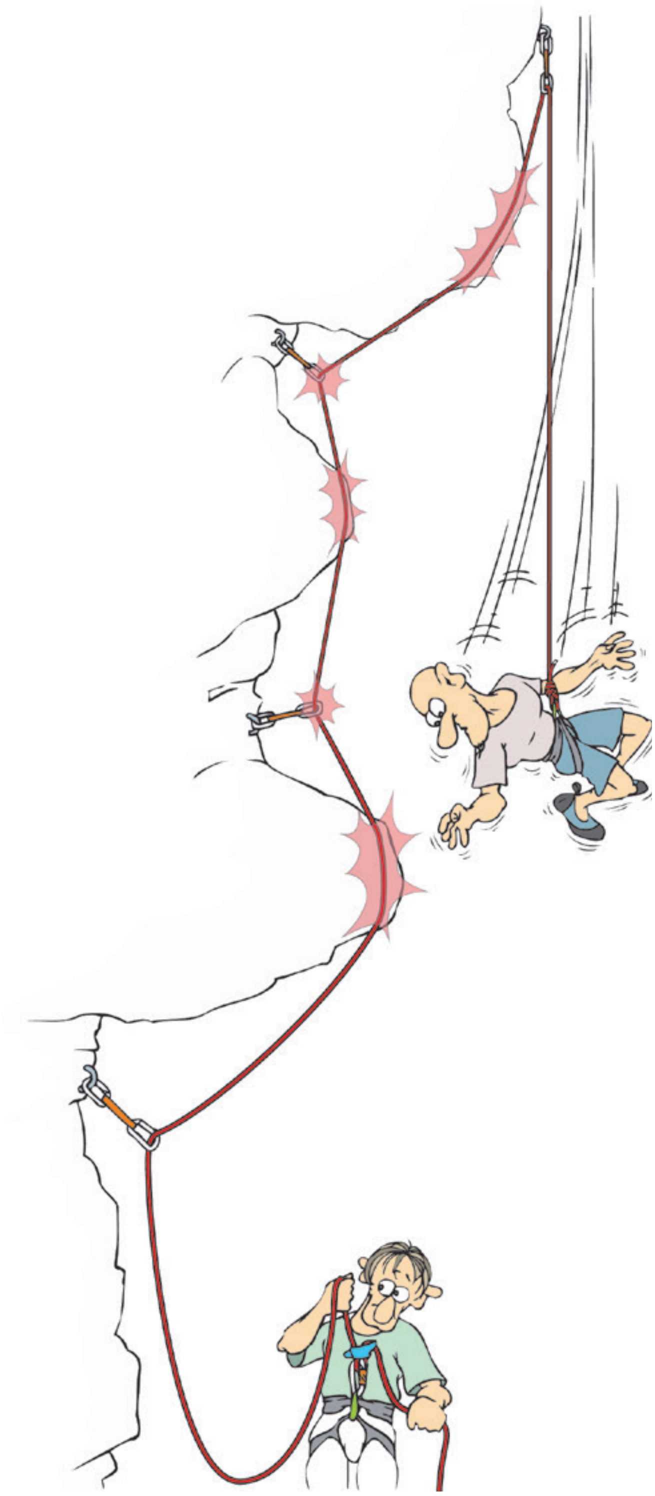


Fig. 72 Unfavorable positioning of the bolts creates unnecessary rope drag.

Top anchors and belay stations

Top anchors at crags are particularly critical from a safety point of view. They are the only belay point for the climber when the route is cleaned, i.e. when the intermediate belays are removed during lowering after the ascent, and sometimes during toprope climbing, and therefore must not fail. The same applies to belay stations in multi-pitch routes that are equipped with bolts. Although it can of course never be ruled out that external influences will damage bolts, climbers expect drilled anchors to be reliable, especially if they are equipped with modern material and are not externally damaged.

It goes without saying that top anchors and belay stations are only installed in solid rock. It is sometimes discussed whether it is sufficient to place only one glue-in anchor. This is supported by the fact that—if the bolt is without defects and has been set professionally—no failure is conceivable under the forces occurring during climbing. Moreover, in many traditional climbing areas, anchors have always consisted of only one glue-in bolt. On the other hand, production-related defects cannot be ruled out, even with bolts, and errors in setting bolts cannot be completely ruled out. So, it could happen that in the summer of 2020 in the Frankenjura , where there are over 10,000 routes with only one glue-in anchor as the top anchor, a top anchor broke for the first time. The shaft of the accident bolt protruded more than one centimeter from the rock, so that the leverage eventually probably led to a cyclic loading failure.

The DAV Safety Research Department recommends the use of two bolts at these safety-critical points to provide redundancy in the case of the failure of one bolt. Optimally, one of them is unloaded, thus representing a "cold redundancy" to the first one. If, in addition, two different bolt systems are used, even possible problems on the bolt side are excluded (in rock for which, in principle, only one bolt system is suitable, this is of course not sensible).

The same quality characteristics apply to both top anchors and belay stations—in addition to the bolt system-specific criteria:

- Compact, even large-scale solid rock
- Professionally placed bolts (one above the other, slightly offset to the side)
- 30 cm distance between the bolts (possibly more when using long bolts in soft rock, for more details see chapter 7 "Placing bolts")

In popular areas, it is advantageous to use replaceable elements because of the abrasion problem. But also, the users are encouraged to think and, for example, not to toprope directly off the bolt, but instead to toprope off their own carabiners.

Fig. 73 Example of an anchor abraded by topropes.

Top Anchors: Examples

Regarding the anchor, the costs and material requirements must often be weighed against the expected frequency of use. In frequently climbed areas, systems are recommended that make accidents due to errors in "threading" impossible: the two bolts are already connected, and the rope only needs to be clipped into the carabiner. "Complete systems" (so-called "safety bolts" according to EN 959) can be purchased from various manufacturers.

Overall, the following points should be noted:

- All components of the anchor that are physically in contact with each other are made of the same material
- Connecting element (typically a chain) with 25 kN guaranteed tensile strength
- If (for example for cutting to length) maillons (according to the "Quick Link" standard) are used, then they must be tested according to EN 12275 with a guaranteed minimum breaking strength of 25 kN in the longitudinal direction (recognizable by the "CE" mark including 4-digit test number!)
- Optional: fixed carabiner in the lower bolt
- Recommendable: use purchasable complete solutions - here it can be assumed that the individual components are optimally matched to each other; Attention: Observe the operating instructions!
- No textile material on anchors, it is too susceptible to aging effects!

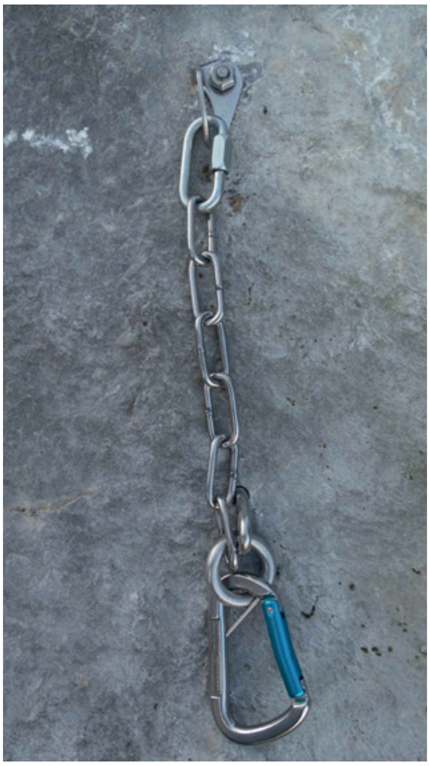


Fig. 74 A cut-to-length anchor with two different types of bolts that can be adapted to the rock conditions.

Fig. 75 A complete system with two glue-in anchors for homogeneous, good rock quality.

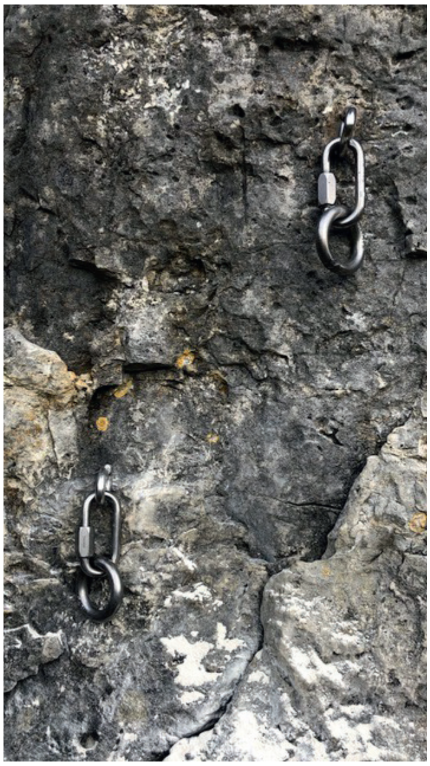


Fig. 76 An anchor without chain: also, here two fixed carabiners can be installed, so that the error-prone threading is not necessary. The additional elements attached with the Maillon Rapide can be replaced without problems if they are worn in by frequent lowering. Also suitable as a belay station where you can rappel.

Belay Stations: Examples

Just as with the top anchors, there are also complete solutions for this situation that must meet the standard requirements for "safety bolts" and the instructions for use must be followed when installing them.

In alpine terrain without bolts, different rules apply. Here, the demands on competence and knowledge in the handling of safety equipment require even higher competence on the part of the users!

Fig. 77 Example of a complete set for belay stations that are also used as rappel stations.

Fig. 78a A multi-pitch belay station: Two bolts set one above the other, the lower one at chest level. Here, a redundant anchor can be simply built and conveniently used.

Fig. 78b A rappel station with textile connection as a compromise solution in alpine and high alpine areas: two bolts can be connected with kernmantel cord as shown to form an abseil station (the thicker, the more resistant—here a piece of single rope; sling material is not suitable). Textile material ages and must therefore be critically assessed and replaced if necessary!

Fig. 78c Glue-in bolts without sharp edges that can be threaded are also suitable as multi-pitch belay and rappel stations. When using express anchors, each needs to be equipped with only one chain link.

Conservation aspects

Fig. 79 Ruine Leienfels in the Frankenjura. Photo: Steffen Reich

The cliff ecosystem bears witness to extreme living conditions. High temperature contrasts, drought, exposure, and nutrient scarcity allow only specially adapted plants and animals to survive there. They must survive unfavorable weather periods and protect themselves from excessive evaporation. These circumstances are used by a small number of specialist species to prevail against competing species in the "cliff" ecosystem. Typical cliff plants grow only on the cliffs and have no chance of survival in the surrounding forest. Many cliff plants are rare and protected by law. Encroachment on this sensitive habitat must therefore be avoided or minimized to a tolerable level.

Climbing and bolting or rebolting of climbing routes can also cause such encroachment and disturbance. For this reason, the German Alpine Club took up this issue more than 30 years ago and has since designed and implemented many measures to protect the flora and fauna of cliffs. In close coordination with the climbing associations, authorities, and nature conservation associations, a variety of different solutions were developed, always depending on regional conditions. A good overview is provided by the publication „Leitbild zum naturverträglichen Klettern in Deutschland" (Guiding principles for ecologically sound climbing in Germany).

The flexible rock closure during the breeding season of rock nesting birds should be emphasized as a climbing-specific protection measure. Through an intensive exchange between cliff supervisors and authorities, blanket closures are avoided, and areas are only closed where it is really necessary. In the Northern Frankenjura, the Eagle Owl and Peregrine Falcon have been so well protected that all known territories are currently occupied. And this with a simultaneous increase in rock climbers.

Species protection concerns can be readily addressed in route bolting and rebolting. Top anchors, for example, protect the cliff top, which is often overgrown by sensitive vegetation, from being stepped on by climbers. Obviously, the route can be arranged to avoid sensitive areas (rare plants, bat and bird roosts). As a bolter and rebolter, defer to the regional supervision structure regarding conservation. Regional representatives of the "Climbing & Conservation" Commission and many other volunteer rock stewards have already coordinated many climbing policies and climbing regulations with the regional authorities. These usually take into account the conservation aspects of bolting and rebolting.

For information on environmentally friendly climbing and contact persons for the climbing areas, see alpenverein.de/natuerlich-klettern.de and dav-felsinfo.de.

Fig. 80 A cliff top with sensitive vegetation and top anchor. Photo: Steffen Reich

Climbing ethical aspects

A separate brochure or even a separate book can probably be devoted to the topic of ethics. Since the first written documentation of "climbs of the peaks" in the Elbe sandstone region at the end of the 19th century, the style and ethics of climbing, respectively, are discussed. Classical alpinism is to be left aside in the discussion here. Climbing has evolved in its form very differently, especially the unimaginable increase in climb difficulty and climbing ability. The development of climbing ability often required going to the limit of falling was only possible due to the addition of improved protection with cemented or glued bolts that in turn improved the risk calculus. The equipping of the climbing routes with so-called safety bolts by private individuals and the alpine associations made climbing interesting for large parts of the population as a form of recreation. Due to the bolt-driven change in perspective, sport climbers also came to focus on rock areas that had remained unnoticed due to their short height or "unclimbability."

Thus, in the low mountain ranges of Germany, there was an ongoing development of climbing crags. Due to the geological conditions, but also due to different views of the bolters, regional "rules of the game" developed in the important regions—the climbing ethics. These regional rules can be broadly defined, circumscribing a variety of different criteria that concern the climbing itself but also the bolting and rebolting. However, they are not based on any legal foundation, but on voluntary compliance. Therefore, in connection with a technical recommendation of the present bolt brochure, there must always be a reference to the "regional climbing ethics." On the one hand, it is about the equipping of climbing routes with safety bolts, but on the other hand, it is also about the execution of the bolting itself. Since these are also not regulated by law, one can accordingly only appeal to the bolters and rebolters.

The volunteer supervisors of climbing areas are often well networked with each other across the boundaries of associations (DAV, IG Klettern, PK, etc.) and often work together in working groups. This collaboration also resulted in the "First ascent and rebolting charter for rock climbing routes", which was also adopted by the Austrian Alpine Association. This charter guides all rebolting and bolting activities in climbing areas.

Due to the increase in climbing gyms, the number of climbers also increased significantly. By far not all climbers go from the gym to the rock, but a large proportion of them do. As a result, especially in well-developed climbing areas with a large number of routes of moderate difficulty, the frequency of use has increased many times over and the bolt material is subjected to heavy stress. But the number of ascents has also multiplied in difficult classic and vogue routes. This trend is being recognized in climbing regions and is being addressed within the regional climbing scene in an ongoing discussion on climbing ethics. The last development, however, also brings with it the conflict of "climbing gentrification" of unbolted rock, which ends in indiscriminate bolting or in the overdevelopment of routes that are undesirable in the "scene."

At this point it must be mentioned that our climbing cliffs are (often) home to rare animal and plant species and (often) not owned by the climbing community. Thus, we climbers are in a sense an imposition on the land manager and the ecosystem. The sport of climbing should be conducive to our recreation in nature. We will certainly succeed in getting along better in the climbing areas with respect and tolerance rather than with a bitter dispute about climbing ethics.

More safety at the cliff - Action “Safe Climbing

In 2005, the DAV launched the „Safe Climbing“ campaign. The goal is to educate all climbers as well as trainers and instructors about correct behavior, possible sources of error, and hidden dangers. This is intended to reduce the rate of belaying errors and prevent accidents. Behind the well-known prevention brand are various building blocks that are didactically coordinated with each other. The most important elements are the DAV climbing certificates Top-rope and Lead-climbing, where the participants are taught the most elementary techniques in a standardized way. In addition, there are other elements such as the partner check campaign and the „Safe Climbing“ poster series. All climbing courses of the DAV have incorporated the „Safe Climbing“ campaign; all trainers are therefore called upon to make their courses in the section even safer with measures from the „Safe Climbing“ campaign!

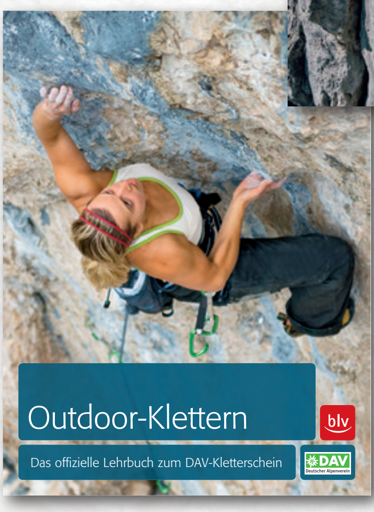
The building blocks:

- DAV climbing certificates Top-rope and Lead-Climbing
- The partner check campaign
- „Safe Climbing“ poster series
- The book “Indoor-Klettern” (“Indoor Climbing”)
- Video library
- The book “Draußen ist es anders” („Climbing outside is different“)
- Climbing certificate Outdoor
- Belay update for climbing certificate lead climbing
- The book “Outdoor-Klettern” (“Outdoor Climbing”)

DAV Climbing Certificate Outdoor

How does rock climbing work? How to belay? How to experience nature and the environment and protect them at the same time? The new outdoor climbing certificate teaches the most important aspects for single-pitch routes outdoors. Pedagogically proven, the contents are clearly presented in a brochure for examiners and participants.

More info at
www.sicher-klettern.de



Safety update for the DAV climbing certificate Lead Climbing (indoor)

This module is intended for all climbers who have already taken the lead climbing certificate and would like to continue their education. The contents of the module, the procedure and the organization are summarized in a new brochure.

Topics include belaying close to the ground, choice of belay device, fall test/belay training, and an exam to check learning success. Those who pass the exam will receive a sticker with the year, which should be affixed to the existing lead climbing.

More info at
www.sicher-klettern.de

New!

- **Climbing rules**
- **Bouldering rules**
- **Gym rules**
- **www.sicher-klettern.de**

Order now online at dav-shop.de or by mail to dav-shop@alpenverein.de

First ascent and rebolting charter for rock climbing routes

The German Alpine Club and Austrian Alpine Club Positions and Guidelines for Action

DAV Deutscher Alpenverein   alpenverein österreich

Decided by the executive committees of the DAV and the ÖAV on December 12, 2010

Preamble

Rock climbing is one of the most popular climbing disciplines and is widely experienced as a popular recreation and a competitive sport; the popularity of rock climbing is heavily influenced by the prevalence of indoor climbing. Many climbers who start climbing on artificial walls are sooner or later drawn to the low mountain ranges and to the Alpine valleys; and many sport climbers also want to go multi-pitch climbing on high rock faces in the Alps. Because of these trends, the climbing community has become accustomed to numerous existing bolts. Concurrently, expectations for bolted protection on rock climbs has risen, with a simultaneous decrease in the willingness and ability to use traditional protection equipment (e.g. nuts and cams). In contrast to the standardized protection of stereotypical artificial wall routes, however, the protection spectrum in rock climbing is very different and ranges from very well equipped plaisir routes to the classics, to sparsely protected adventure climbs. And as varied as the degree of protection and route character are on the rock, so are the spaces in which rock climbing takes place. There are modern, fully equipped climbing crags and the traditionally protected rock-climbing areas; the transitions are now fluid. In many cases, the most diverse route types even exist directly next to each other.

The German Alpine Club (DAV) and the Austrian Alpine Club (ÖAV) promote a development that takes into account the needs and demands of the different user groups in rock climbing and also takes responsibility for the history of the sport of climbing. They want to contribute to a balanced route development, so that climbing continues to be a sustainable sport for future generations.

As a voluntary commitment, this “First Ascent and Rebolting Charter” is intended to serve as an orientation for the aforementioned activities and to contribute to the establishment of “good style.” In particular, the DAV and ÖAV call for a sensitive and coordinated approach by the individual activist or the acting groups.

Principles

- Very well bolted climbing routes (“plaisir climbs”), “old” classics, and climbs that are not fully equipped with bolts (“adventure routes”) all have their justification.
- The climbing traditions of a region represent a special value. They include a variety of styles and local characteristics. These are to be preserved and further developed jointly.
- As a rule, alpine routes (classics) must not lose their original character. This is especially true for outstanding alpine landmarks.
- Local climbing regulations, aspects of nature conservation and environmental protection and, if necessary, legal requirements must be taken into account during first ascents and rebolting.
- Rock climbing is hazardous. Each climber must decide for themself whether they are up to the overall requirements of a route and can climb it according to their own risk assessment after weighing the risks.
- Anyone who opens up or rebolts a route at a crag or in the mountains using bolts is not currently assuming any legal duty and therefore does not have a duty to ensure public safety. However, since it is to be expected that the route will also be used by other climbers, care and conscientiousness must be exercised when installing bolts.
- Established crags—in the sense of planned development of numerous climbing routes as opposed to individual random stringing together of routes by different people—should be regularly inspected and maintained.

Policies for rebolting

MAXIM We strive to preserve the original character of all climbing routes, especially those with historical significance. This means that climbers should refrain from increasing the number of fixed anchors on a route.

This can be waived if there is agreement at the local level—this includes the agreement of the first ascenders—that the number of intermediate anchors should be changed by adding or removing anchors.

(Tyrol Declaration)

Implications for practice:

1. The setting of additional bolts and the removal of existing bolts may only be carried out with the consent of the first ascender. If the opinion of the first ascender cannot be obtained, representatives of the local climbing associations and clubs shall decide.
2. During rebolting, care should always be taken to preserve the route character and line of the initial ascent.
3. Passages that were first climbed with traditional protection devices should not be subsequently equipped with bolts. If a significant natural protection unit can no longer be used or its failure is foreseeable, a bolt can be placed at this point.
4. Where possible, the number of permanent anchors left in a rock-climbing route should be reduced by the rebolting, e.g. several normal pitons can be replaced by a single bored bolt.
5. The difficulty of a rock-climbing route should not increase as a result of the rebolting. Pitches that were first climbed with the help bolts should still be manageable with the help of bolts after rebolting. On such pitches, normal pitons are recognized as acceptable points of support.
6. Bolts are set mainly at safety-critical points and belay stations. Exceptions to this rule may be belay stations where a belay station can be established without the use of chocks, e.g., by threading cord or tying off a tree or chicken head. “Safety-critical” - Definition:
   - It is not possible or very difficult to equip with traditional protection.
   - The average climber needs a reliable anchor at this point.
   - Failure of the protection would likely result in serious injury.
7. For all rebolting actions, only material that complies with the valid European and UIAA standards may be used. The rebolting must be carried out professionally.

Policies for first ascents

MAXIM The first ascent of a route, like the first ascent of a mountain, is a creative act. It should be conducted in a style that is at least consistent with the “climbing ethic” common to the region in question and demonstrate responsibility to the local mountaineering community as well as the needs of future generations.

(Tyrol Declaration)

Implications for practice:

1. During first ascents, local conditions, aspects of nature conservation and environmental protection and, if necessary, legal requirements must be taken into account.
2. Within this framework, the first ascender is free to choose his style of development and the standard of protection of his route.
3. The first ascender refrains from altering the rock by hammering or attaching holds.
4. The independent character of neighboring climbing routes should be impaired as little as possible. Adventure routes in particular must not be tamed by “crossing”, abseiling routes or similar.
5. First ascents of alpine routes are always made from the bottom. In established plaisir climbing areas, routes can also be equipped from above.
6. The DAV and OeAV finds it useful to establish suitable routes for courses, training purposes, and for getting started with rock climbing. Classics, however, may not be altered for this purpose.

Appendix

The tested bonding agents correspond to the products available on the market in 2018.
As needed, this list will be updated online at https://www.alpenverein.de/bergsport/sicherheit.

In the course of the pull-out tests conducted by the DAV Safety Research Department, it was found that all bonding agents selected for glue-in bolts in limestone and granite delivered values above the standard requirement according to the criteria listed on page 16. It follows that bonding agents selected according to these criteria, approved for heavy-duty use and suitable for natural stone, are generally suitable for glue-in bolts in solid rock—unless otherwise stated in the manufacturer's specifications.

Properties of current cartridge bonding agents (as of 2018):

	HILTI HIT-HY 200A	HILTI HIT-RE 500V3	Fischer FIS V	Fischer Green	Upat UPM 55	Upat UPM 44	Würth WIT-VM 249	Würth WIT-Nordic	MKT VMU plus	Bossong V Plus	Bossong Epoxy 21
Basis	Expoxid-harz	Metha-crylat	Vinyl-ester	Vinyl-ester	Expoxid-harz	Vinyl-ester	Vinyl-ester	Vinyl-ester	Vinyl-ester	Vinyl-ester	Expoxid-harz
suitable for uncracked concrete	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢	🟢
Processing time (at 15° C in minutes)	short (7)	long (60)	short (5)	short (7)	long (30)	short (7)	medium (15)	long (55) bei −15°C	medium (15)	medium (11,5)	long (70)
Curing time (at 15° C in minutes)	short (45)	long (12 h)	short (60)	medium (90)	long (18 h)	short (60)	medium (80)	long (16 h) bei −15°C	medium (80)	short (45)	long (22 h)
suitable for Water in borehole	🔴	🟢	🟢	🔴	🟢	🟢	🟢	🟢	🟢	🟢	🟢
suitable for Overhead mounting	🟢	🟢	🟢		🟢	🟢	🟢	🟢	🟢	🟢	🟢
Price (for 100 ml)	11,60 €	12 €	4,50 €	3,70 €	7,70 €	5,30 €	7,30 €	7,90 €	8,40 €	3 €	4,50 €
Installation temperature in °C	+ 5 to + 25	+ 5 to + 40	− 10 to + 40	+ 5 to + 40	+ 5 to + 40	− 10 to + 40	− 10 to + 40	− 20 to + 20	− 10 to + 40	+ 5 to + 30	+ 0 to + 30
Temperature resistance in °C											
short term	120	70	120	80	72	120	120	120	120	120	80
long term	72	43	72	50	50	72	72	72	72	72	50

Tbl. 6

Properties of current glass bonding agent capsules (as of 2018):

	Fischer-RSB	Mungo	MKT	Würth	Upat
suitable for non-cracked concrete	🟢	🟢	🟢	🟢	🟢
Curing time (at 15° C in minutes)	20	60	60	60	20
suitable for water in borehole	🟢	🟢	🟢	🟢	🟢
Installation temperature in °C	+ 5 to + 40	0 to + 30	mind. + 5	0 to + 30	− 15 to + 40

Tbl. 7

Overview of the compatibility of the glass bonding agent capsules tested in 2018 with different bolt diameters and lengths:

Bolt diameter **12 mm**

Bolt length	75 mm	90 mm	100 mm	105 mm	110 mm	120 mm	150 mm
RSB 12	🔴	🔴	🔴	🟢	🟢	🔴	🔴
RSB 12 mini	🟢	🔴	🔴	🔴	🔴	🔴	🟢
Mungo M12	🔴	🟢	🟢	🟢	🟢	🔴	🔴
MKT M12	🔴	🟢	🟢	🟢	🟢	🔴	🔴
Würth M12	🔴	🟢	🟢	🟢	🟢	🔴	🔴
Upat M12	🔴	🟢	🟢	🟢	🟢	🔴	🔴

Tbl. 8a

Bolt diameter **10 mm**

Bolt length	75 mm	80 mm	100 mm	120 mm
RSB 10 mini	🟢	🟢	🔴	🔴
Mungo M10	🟢	🟢	🔴	🔴
MKT M10	🟢	🟢	🔴	🔴
Würth M10	🟢	🟢	🔴	🔴
Upat M10	🔴	🟢	🔴	🔴

Tbl. 8b

Bolt diameter **8 mm**

Bolt length	80 mm
RSB 8	🟢
Mungo M8	🟢
MKT M8	🟢
Würth M8	🟢
Upat M8	🟢

Tbl. 8c

Climbing naturally

Without a doubt, climbing has become a mainstream sport. On the one hand, this is a wonderful development. On the other hand, where there are many people, there are always problems. Climbers are no different than anyone else in the world. Specifically, the problems with climbing arise mainly where many people go from the gyms to the crags—because the crags are home to endangered species, locals live there, and there is limited parking. These things are by no means unsolvable, quite the contrary! It comes down to us, the climbing community. On how we behave. The rules are quite simple and easy to follow.

The DAV campaign “Climbing naturally” contains information about the most important rules for equitable and nature-friendly climbing in nature. This includes having fun and experiencing your limits. But also to be considerate of the environment and the people around you.

Detailed information on the rules and the campaign is available at **alpenverein.de/natuerlich-klettern**

DAV crag info

Further qualified advice on climbing on natural rock is provided by the DAV-Felsinfo (crag info). At dav-felsinfo.de, all information on nature-compatible climbing is collected. The portal contains profiles and pictures of about 5000 climbing areas throughout Germany. Notifications of temporary closures due to bird breeding and many other notices are updated on an ongoing basis. In addition, it contains a lot of background information on climbing and on the natural environment in around 30 climbing regions from the southern Black Forest to Elbe Sandstone.