BOLTS

A GUIDE FOR INSTALLERS

Introduction

This guide is aimed at climbers who intend to place bolts, either for new routes or when re-equipping existing sport climbs. It combines a wealth of experience and knowledge gleaned from many sources, and reflects the content included in bolting workshops provided to volunteer groups around the country by the BMC. At the time of writing the information is as up-to-date as possible, but it should be borne in mind that this is an evolving field and that over time new practices and products may become important.

The guide is written assuming that the reader has little to no previous bolting experience. We explain how to choose suitable equipment to use, and outline good general installation practice. Greater detail is provided in the appendices, including recommended equipment to use. These also provide more background to the recommendations and include information of interest to the more experienced bolter and to those of an enquiring mind.

Photo: A typical UK sport climbing crag

Liability and insurance

Before you begin bolting, it is important to consider the consequences if you get something wrong. Most serious climbing accidents occur as a result of user error or distraction, for example, failing to correctly tie into the rope, or being lowered off the end of the rope. Much less common is the failure of a bolt or belay. Who bears responsibility in this case, the climber or the person who equipped the route?

The BMC has obtained legal advice that confirms our view that climbers bear the overall responsibility to understand the risks associated with climbing, and to manage these appropriately for themselves. There is also an expectation with sport climbing that climbers should be aware that routes are not maintained or inspected, and that therefore climbers must be prepared to accept the risk that a route may have become dangerous after it was originally created.

All climbers should understand and accept the following BMC Participation Statement:

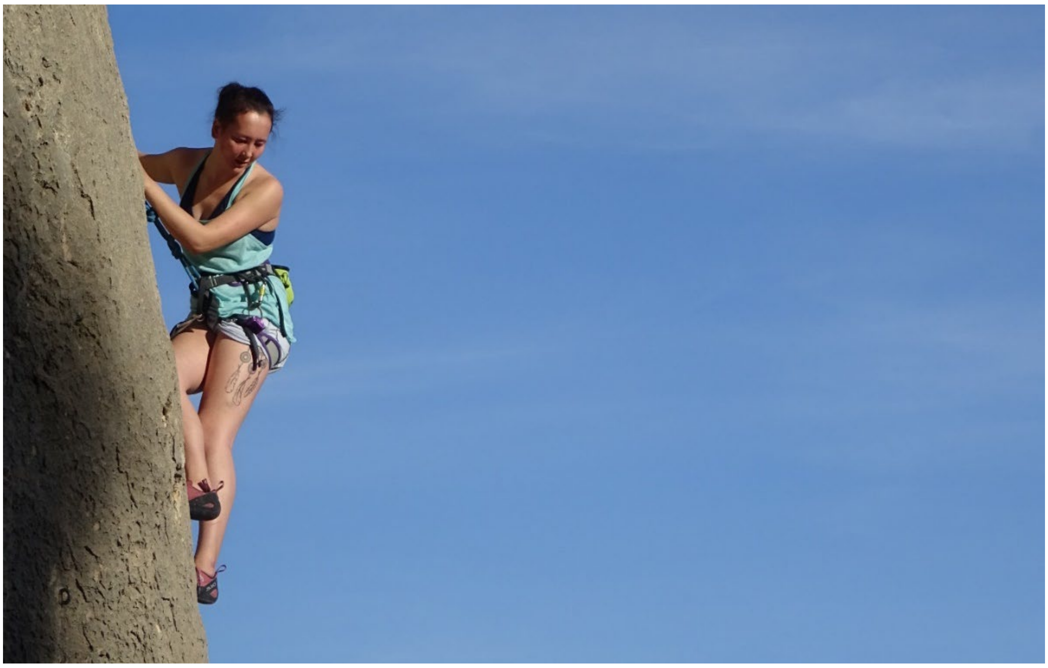
The British Mountaineering Council recognises that climbing and mountaineering are activities with a danger of personal injury or death. Participants in these activities should be aware of and accept these risks and be responsible for their own actions and involvement.

It is also reasonable for a climber to expect that the original installation of any bolts was competently done using suitable equipment. This guide aims to help provide advice about how to do this, both to satisfy any responsibility to those climbing your routes after you have bolted them, but also to enable them to better enjoy them. There is also the issue of sustainability – better, longer lasting bolts mean better, longer lasting routes.

A final point is worthy of note - as part of the insurance cover provided as part of BMC membership, in the very unlikely event of a bolt installer being found liable in the event of a bolt failure, they would have liability cover as long as they are a member when the claim against them is made.

Access, conservation and ethics

Many sport climbing venues lie in areas with potentially problematic access. Sites may be shared with other users such as walkers and anglers. Landowners may be concerned over liability for fixed equipment. There may be reasonable access restrictions because of rare or endangered plants, wildlife or geological and archaeological features. Before you switch on your drill, think carefully about the impact you will make, both immediately and in the longer term. Not only is there little point in bolting a crag only to lose access to it, but these actions never occur in a vacuum – a poor reputation created by infringements will soon spread to landowner groups and stakeholders, potentially leading to access problems at other venues in the future. If in any doubt regarding whether bolting might endanger access, consult first with a member of the BMC Access and Conservation team.



Many areas of the UK have a unique history when it comes to the evolution of sport climbing. Before bolting a new route, think carefully about whether it is appropriate. Will it impinge on existing traditional routes, or alter their character? Doing so is not generally acceptable and could well result in your hard work being undone. When re-bolting existing climbs, you should ideally consult widely first before adding any extra bolts. In many cases this may be totally fine and indeed is often welcomed, but not always, so it’s best to check first whether that’s through your BMC local area or through one of the forums or climbing social media groups.

Personal safety

It is outside of the scope of this document to provide detailed advice regarding safe methods of working, but some general advice is given for those competent to work safely at height. Rule number one is to stay safe. Equippers have been killed or seriously injured in the past whilst doing their work, so think carefully about how you are going to safely access the routes you plan on equipping. Before you start, do a risk assessment and have a plan for if things go wrong and you need to be rescued. Some basic things to consider:

- If aiding up on existing bolts, how trustworthy are they? What will happen if one of them fails?
- If abseiling in from above, are you likely to damage your rope on any edges and is there loose rock which could be dislodged and hit you or your rope?
- Have you told anyone where you are working, and do you have phone signal if you need to call for help?

Try and avoid working alone – tagging along with a climbing pair who can keep an eye on you works well if you are the only person bolting. As well as yourself, consider the safety of other people who may be below you as you work. Your equipment should be equipped with a suitable tether to prevent dropping it, and you may choose to use signs or a ground-person to warn passers-by where appropriate.

Photo: Would you feel safe aiding on this bolt?

Bolting equipment list

Equipping routes requires time, energy and plenty of enthusiasm. It also requires a fair amount of equipment, some of which is quite expensive.

Photo: Bolting kit for glue-ins. Drill, cleaning kit, PPE, bolts and resin

Basic kit

SDS cordless hammer drill: choosing a drill is a balance between one that is easy to wield but that has plenty of power and endurance. The impact energy measures the power of the hammer action of the drill, aim for something above 2J as an absolute minimum. The amount of charge a battery holds is measured in Ah, and although more is better, larger batteries also tend to add weight, so a better option than 1 x 8Ah battery is to have 2 x 4Ah ones.

Drill bits: use high-quality SDS drill bits to drill fast, true holes. A true (straight and perfectly round) hole is important to obtain full holding power with expansion bolts.

Rock hammer: for removing loose flakes, checking overall rock soundness and marking drilling points you'll need a hammer with a pick on it. When placing bolts avoid using a carbon steel hammer - this will contaminate the bolt with iron which can lead to corrosion. Either use a stainless steel rock hammer, or a hammer with plastic or rubber shims.

Brush and pump: essential items for cleaning out the dust from drilled holes. Use a good quality blow pump and hole cleaning brushes which are the correct size for the drilled hole.

Bolt bag: something to carry your bolts and other small loose items in which can be clipped to your harness or carried over the shoulder.

Abseil equipment: you'll need equipment to access the route. Low-stretch ropes, ascenders, and a descender are pretty much essential. A clipstick and rope protectors may be useful, whilst protection including skyhooks, nuts and cams may be needed to help with positioning. Given the potential hazards of working with power tools and in areas with loose rock, the use of a backup rope is well advised, as is wearing a helmet.

Old clothes: bolting is a dirty, messy business – wear old clothes and shoes in preference to your newest outdoor clothing.

For placing expansion bolts

Torque wrench or spanner: for placing expansion bolts you'll need a spanner or a torque wrench. For 10mm bolts a 17mm spanner or socket is required, for 12mm bolts a 19mm one.

Photo: A selection of different expansion bolts

For placing resin bolts

Photo: A selection of modern resin bolts

Resin applicator: the most common way of applying resin is with a dispenser gun, into which a resin cartridge is placed. Make sure the dispenser matches the type of resin cartridge used. Some people make an improvised holster from a plastic bag and some pipe cut to size. This helps avoid getting too much dripping resin onto your clothes, rope, and shoes.

Caption: Coaxial resin tube on left, in-line on right. Each needs a specific dispenser.

Spare mixer nozzles: each resin cartridge comes with a mixer nozzle. Spare nozzles allow you to pause or stop applying resin without wasting the rest of the cartridge. The resin will set in the nozzle but once the nozzle is replaced you can start again.

Disposable gloves: useful for protecting the hands from resin and can be used to smooth and tidy the resin installation. Used gloves are also handy for squeezing waste resin into and allowing you to keep a resin sample to check correct curing.

Warning tags: depending on the cure time of the resin used, you may need to prevent use of the route whilst the resin fully cures to full strength. A warning tag or some red tape on the first bolt is a must for these situations.

Choosing suitable equipment

The old adage “buy cheap, buy twice” generally holds true for bolting. With limited amounts of rock to play with, it really is essential to use high quality bolts and lower-off components both for the safety of others and for the long-term sustainability of the sport. The effects of repeated placement of sub-standard bolts were once a blight on places such as Yosemite in the USA, where the combination of a ban on power drills and the hardness of the granite lead to belays sporting clusters of bolts, none of which were fully trustworthy. Fortunately, there the problem has begun to be addressed by www.safeclimbing.org and the AAC (American Alpine Club) with a combination of education and funding for anchor replacement. Closer to home, the BMC support bolt funds with workshops, and has in the past donated thousands of pounds worth of bolts to them. This document provides a useful resource for reference and for guidance on choosing equipment that is both cost-efficient and long lasting.

Bolts

Bolts historically have one of three origins: self-made anchors, adapted industrial fixings or certified rock anchors. Certified rock anchors conform to the EN959 standard and are designed specifically for rock climbing use [1]. Using anything else requires you to interpret and assess the specifications or your design carefully to ensure that they are fit for purpose and will remain so for their expected lifetime. This adds a considerable burden of liability upon you, as if it ended up in court, you might have to explain why you used something which did not conform to the accepted standard for the application.

Whatever the source, it is essential that the bolt is both a suitable design and made from an appropriate material for the rock type and location where it is to be installed. The first important decision is whether to use expansion bolts or resin bolts (also called glue-ins). The second decision is whether to use stainless steel bolts, or a more expensive but more corrosion resistant material. For an introduction to the basic types of bolts, refer to our climber's guide to bolts [2].

Expansion bolts are simple to place and can be used immediately, but are not suitable for all situations. A good rule is to consider stainless steel expansion bolts as the default option when equipping new routes, and then look at factors which might cause resin bolts and/or more exotic materials to be used instead.

Photo: An interesting home-made belay anchor

Re-equipping: correctly specified resin bolts have an exceptionally long lifetime. When re-equipping a route, consider resin bolts to be the default option. Re-equipping implies that a route is popular enough or good enough to be worth the effort of using glue-ins. Opting for the longest lasting solution when re-equipping reduces the number of bolt placements in the long term and can extend the lifespan of the route.

Popularity: resin bolts are generally very strong, and will generally stand up better to sustained, intensive use than expansion bolts will. This makes them the ideal choice for very popular crags and routes.

Rock type and quality: for testing purposes bolts are placed in a block of standard concrete with a compressive strength of 50MPa. In the field, rock quality and hardness can vary a great deal and this should be taken into account when choosing the bolt type to place, as they may not perform as well as in their test specification. 10mm expansion bolts are only suitable for hard rock, whilst 12mm expansion bolts can be used on hard to medium rock types. By choosing a longer length as the rock gets softer, resin bolts can be used on almost any climbable rock type. Some rock may contain voids, cracks or weak layers, in which case resin bolts are also preferred. See Appendix A for rock compressive strength data.

Corrosive environment: environments are split into three classes in the update to the EN959 standard. Each class has a range of specified materials which may be used, and a description of the intended usage location. It is worth noting that resin bolts generally have a better resistance to corrosion than expansion bolts for a given material class, especially if they contain no exposed welds, and that forthcoming standards are likely to recommend designs and manufacturing methods which aim to minimise the various forms of corrosion which have been found to affect anchors. See Appendix B for a discussion of corrosion issues found in climbing bolts and belays and Appendix C for the EN959 classification table.

Choosing a belay

A belay is used to lower-off or abseil from, and generally consists of two bolts and some additional components. The bolts used will need to be chosen using the criteria for protection bolts as outlined above.

Until recently there was no standard for belay sets or components, so purpose-made belays from bolt manufacturers were made from EN959 bolts with additional components obtained from a variety of sources. This changed with the recent update to the EN959 standard, which now includes a standard for those belays which include two bolts linked together, usually by a chain.

Photo: A belay set bought complete

Whether bought complete or assembled using components yourself, there are two important rules for belays.

- Always use components made from the same material, otherwise the belay will be subject to a dangerous form of decay called galvanic corrosion. Typically, this means components and bolts which are all made of AISI 316 grade stainless steel.
- All components should be rated as load bearing. A minimum breaking load of 25kN is given in EN959 as a requirement for all components of a belay. This means that any additional components, which may be subjected to wear, are at least as strong as the anchor bolts in their strongest orientation.

There are a number of different formats and options for lower-offs, and which is best depends on a number of factors.

The simplest format is a pair of belay bolts. These are either resin bolts with a larger eye or expansion bolts fitted with a special belay hanger. Each has enough room to thread a bight of rope through whilst having a karabiner also attached to them and provides a rounded radius which doesn't damage the rope as the climber is lowered.

These have a low visual impact, which is useful for venues where bolting is barely tolerated by the landowner, and they also give the most placement versatility which is important when the rock quality is poor.

Photo: Titanium belay anchor

On the more popular routes and crags, wear of the lower-off bolts can become a major problem, particularly where bottom-roping is common. In these cases, it is important to have some form of replaceable and hard-wearing component to lower-off from, which when worn can be replaced leaving the bolts themselves intact. Historically climbers have left old karabiners on the bolts, but these rapidly seize up and decay because of galvanic corrosion.

One option, which can also be retro-fitted to existing belay bolts, is to attach a belay ring to each belay anchor using a stainless steel maillon. The rings last for a long time as any wear is evenly distributed as they rotate in use. Thread-lock glue on the maillon prevents casual theft, but still allows removal with a spanner when the ring eventually needs replacing. Maillons used alone are cheaper, but wear faster and have a tendency to be undone by movement of the rope.

Photo: Belay bolts showing wear caused by top-roping and lowering

Overall, the ring and maillon arrangement has much to recommend it, but there are two downsides to consider. The most important one is that the rings must be threaded, which requires the climber to untie from the rope. This creates a safety hazard both for novices untrained in how to do this safely, and for experienced climbers who may make an error. Secondly, the rope going through two points tends to cause twisting of the rope, particularly if the belay points are level with each other.

There are other options available which can help solve these problems. Linking the bolts with a chain allows a single point to be used to lower from which prevents twisting of the rope. Curled metal shapes called rams-horns allow lowering without having to re-thread and untie the rope. Stainless steel karabiners give a good balance of security and ease of use. Before considering any of these options, bear in mind that they will have some downsides of their own, and often an increased expense.

Resin

You must use an appropriate resin when installing resin bolts. Resins are two liquid components which when mixed react to form a hard polymer. The most common system is a cartridge which fits into a dispenser gun. As the components are squeezed out of the cartridge by the dispenser, a mixer nozzle combines them and they start to react and harden. Cartridges come in different sizes and formats, which will each require a compatible dispenser. Therefore you will need a resin cartridge, a matching dispenser and one or more mixer nozzles.

Photo: Vinylester and epoxy based resins, in cartridge and ampoule. Polyester based resins are no longer recommended

Less popular are glass capsules containing the resin components. These should generally be used when specified for a particular bolt by the manufacturer, as the amount of resin then matches the space around the anchor. There are two types of capsule – those which require the anchor to be spun in using a drill attachment, and those which allow the anchor to be placed by hand by hammering in and turning the anchor. Hammer-in capsules usually have lower performance than cartridge resins, whereas spun-in perform at least as well if not better. In both types the glass casing becomes part of the resin filler. The main difficulty with both capsule types is their relative expense and their fragility, making them awkward to transport. They are most useful when only a single anchor needs placing.

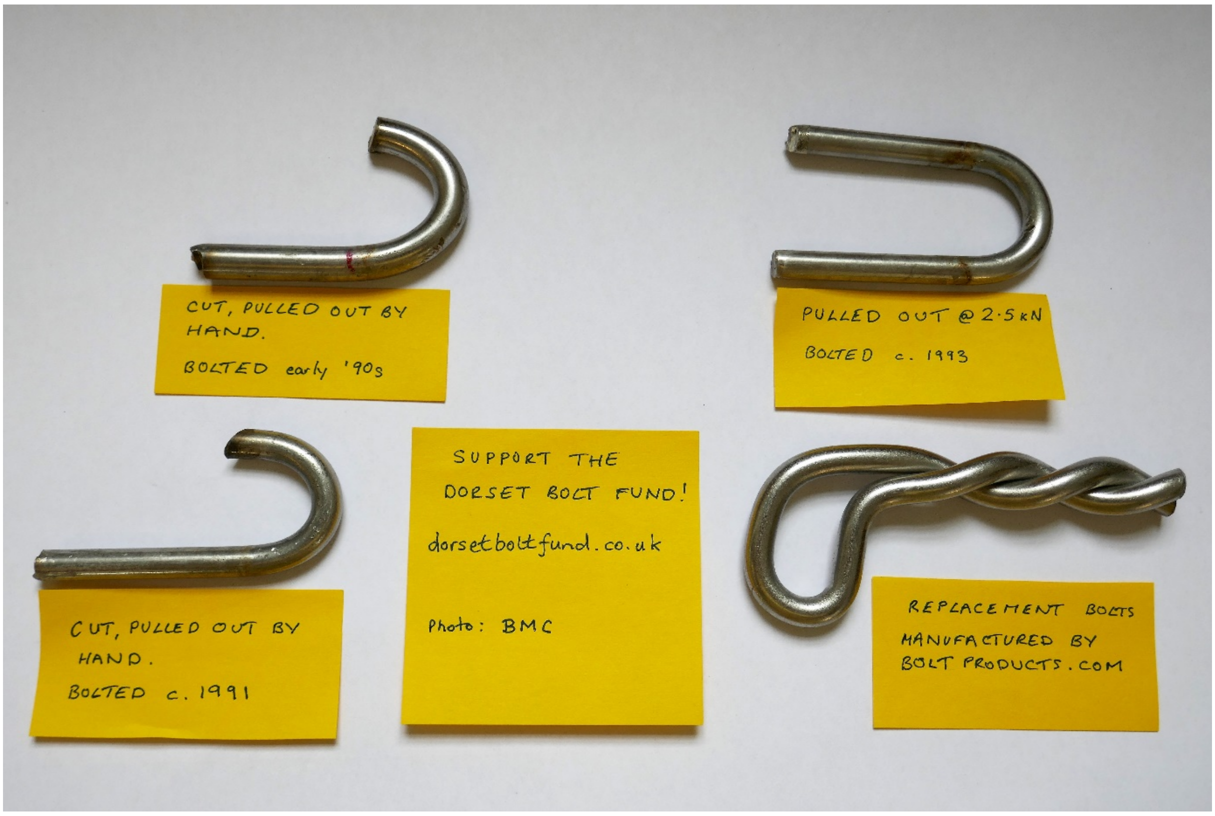


Photo: Replacing legacy anchors in some areas is an urgent task

It's always best to use a resin which the manufacturer of the bolt has specifically recommended because they will have used it during testing to ensure their anchor system meets the requirements of EN959. Sometimes though, the recommended resin may not be available. In this case, choose either a vinylester or epoxy-based resin which has an ETAG certification. Polyester-based resins are not generally suitable, as their mechanical and chemical properties are inferior, and the latest EN959 standard prohibits their use with rock anchors.

Appendices D & E give more guidance and comments on options for anchors and belays.

Good installation practice

In this section we cover the key aspects required to competently place bolts. Although the theory behind placing bolts is relatively simple, in practice things are often less straightforward. In many ways it is an art, where you'll have to use your judgement to make good decisions. Read and follow the manufacturer's instructions and guidance for use and installation, and take note of any material safety data which may pertain to chemical resins used. We give some general guidance in case the manufacturer's guidance is not available.

For new routes, you have the benefit of a blank canvas. A good equipper of sport climbs will endeavour to place bolts which can be clipped from good holds and place them to minimise the chances of a ground fall or impact with ledges. For re-equipping, you may be happy with the existing bolt positioning, in which case you'll hope to place new bolts in roughly the same position as the existing ones.

This assumes in each case that the rock quality is good enough to place bolts at will. Unfortunately, on many of the sorts of rock which are ethically acceptable to bolt in the UK, this is far from being the case. You may not be able to place a bolt in the optimum position required. It is better to have run-outs or hard to clip bolts than to place optimally positioned bolts which may fail because of poor rock.

The best installation practice is to read and follow the advice supplied by the bolt manufacturer. This should include details on the correct drill diameter, hole depth, and any other relevant information. Below we offer some general guidance pertinent to the main bolting options.

Rock quality

How do you assess rock quality and decide on safe positioning? Start with a visual inspection, looking for any cracking, loose rock or any colour changes in the rock which might indicate a band of weakness.

Use your hammer to hit the rock firmly around your proposed placement and listen as well as look at the rock. A dull thud indicates the presence of voids, cracks or a loose block which must be avoided. Now consider the proximity of the proposed placement to any edges, cracks or existing bolt placements. Various factors determine the acceptable minimum spacing, but for our purposes 150mm should be considered the minimum for good quality hard rock. For longer bolts used in soft rock, use a spacing distance of 1.5 times the bolt length i.e. a 150mm bolt used in very soft sandstone will require a minimum spacing of 225mm.

Before you drill your bolt hole, you may need to "dress" the rock surface, flattening it and removing any weak surface layers of rock. This is especially important when placing expansion bolts. A note on drilling depth: most drills have a depth marker system which relies on setting a rod against a flat surface. These don't work very well on a rock surface which often isn't remotely flat! A better option is to mark your drill bit with tape, paint or a marker pen to mark the required depth.

Placing expansion bolts

Where possible refer to the bolt manufacturer's guidance for installation [3].

With your location chosen and the rock surface ready and dressed, drill a hole perpendicularly to the surface. It is important that when placed, the hanger sits flush and level with the surface, to eliminate any leverage effects.

Photo: Tap, flush and then cover with resin and rock dust.

Good practice is to drill the hole deep enough so that at the end of its life, the nut and hanger can be removed from the bolt and the stud hammered in level with the surface. Drill the hole steadily, letting the drill bit do the work. Pushing too hard causes the drill bit to bend and create a hole which isn't true, leading to a weaker than specified placement. Once drilled to the correct depth, clean out the rock dust from the hole using your brush and blow pump.

Adjust the nut and hanger on the bolt so that there is no danger of damaging the thread when hitting the striking surface, and gently tap the bolt into the hole until the hanger is flush with the surface. Adjust the position of the hanger so it is correctly oriented, turn the nut until a minimum amount of stud is exposed and then finish tapping in the bolt. Now use your spanner to tighten the nut, keeping the hanger correctly orientated.

Photo: Loose expansion bolt in slate

Strictly speaking you now should tighten the nut until it is at the torque specified by the manufacturer. Any inability to reach this torque indicates that the expansion collar is crushing the rock inside the hole and the design load cannot be guaranteed. Such bolts often end up as “spinners” in short order. Common practice is to tighten by hand and estimate the torque. For 12mm bolts this is fairly easy, as firm hand tightening with a standard spanner is about the right amount. For 10mm bolts it is rather easy to overdo it and stress the bolt – an old trick is to use a shortened spanner or only use two fingers and the thumb on the spanner to tighten the nut.

Note the length of any exposed stud sticking out from the nut. The stud will be drawn out as you tighten the nut. Petzl recommend between 3mm and 6mm exposed stud for their bolts. Too long an exposed stud has two negative factors associated with it. First, it means that the embedment depth is reduced which can mean a weaker placement than the design specification. Second, the stud can cause a quickdraw karabiner to get hooked up in a weak position and fail when fallen on. If studs are consistently too exposed as you bolt a crag, it suggests that the rock you are bolting isn’t hard enough for the bolts you are using and you probably need to reconsider your options.

Placing resin anchors

The principles of rock quality and positioning are the same as for expansion bolts, although with no expansion forces you can get away with a smaller spacing between bolts and edges, and of course you will be able to bolt softer rocks.

Drill the hole perpendicular to the rock surface, slightly deeper than the bolt is long (+5mm is generally quoted). The manufacturer will normally instruct you to drill a hole of a larger diameter than the bolt shaft, to provide enough space for the amount of glue required to heat up and fully react the mixture. This can create a problem if placing bolts under roofs or on steep rock as the bolt can slide out before the resin sets. Various solutions exist to counter this – some bolt designs have a wider section to snugly fit at the surface, others use an interference fit with wide channels for the glue. Some gaffer tape to temporarily hold the bolt in place can sometimes be useful as well.

Photo: A well installed resin anchor

You also need to decide whether to recess the bolt eye or not. Some manufacturers recommend doing this, others do not. On the plus side, recessed eyes look tidier, have a smaller visual impact if this is important, and are claimed to reduce metal fatigue and crumbling of softer rock around the placement. Conversely, they take extra time and effort, and if done poorly can make it more likely for karabiner gates to drag against the rock and open accidentally. They also make removal at the end of the bolt lifetime almost impossible, although this is somewhat moot as this is not trivial even with non-recessed resin bolts.

We will describe the drilling process for installing a Titan Climbing Eterna 90mm anchor by way of example:

Drill two holes, one vertically above the other using a 14mm drill bit, to a depth of 10mm. Then drill the main hole vertically above these using a 14mm drill bit, allowing 5mm more length than the bolt to leave some space for resin at the bottom of the hole. Drilling perpendicularly to the surface will give maximum placement strength but is less critical than for expansion bolts. Now either carefully drill upwards from below at a 45^{o} angle or use the pick of your rock hammer to shape the channel so the eye fits snugly and flush with the surface.

Now things get critical. Using a blow-out pump and wire brush of appropriate size, clean the hole **at least three times**. The cleaner and more dust-free the hole, the stronger the anchor will be. Once you’ve done this, check that your bolt fits correctly in the hole before you begin to apply the resin.

If installing multiple bolts on a route it’s a good tactic to have all of the holes drilled, cleaned and checked for fitting first so that you can then abseil down and glue each one without too long a pause, as this will save wasting glue and nozzles.

If using a cartridge and dispenser, load a resin cartridge into the dispenser and screw a mixer nozzle in place.

Squeeze the trigger until a bead of resin starts to pump out of the end. You should witness a visible colour change as the two differently coloured liquid components are mixed together. It is important to discard the first part of the mix, a 10cm length of bead should be adequate. A common tactic is to squeeze this bead into a used disposable glove, as this saves leaving a mess, and allows you to check the discarded sample has mixed properly and set afterwards.

Use the release button on the dispenser to remove the pressure if you need to stop more resin being pumped out once you are happy with the mix but need time to get in position to apply resin.

When ready, place the nozzle into the bottom of the hole, and pump out resin drawing the nozzle out as you go. Getting the correct amount is a matter of experience, but aim for roughly filling the hole 2/3rd full, and add a smear of resin into the channel if recessing.

When inserting the bolt, rotate it as you go to help expel any air bubbles. You should end up with a small excess of resin pushed out, which you can tidy up and smooth out with your disposable gloves. Too much glue will require some tidying up, but too little can be disastrous. If you don't initially apply enough resin, work quickly to remove the bolt, add more resin and then re-install the bolt before the resin has set.

If using a resin capsule, follow the manufacturer's instructions, and do not confuse the ones acceptable to be hammered in rather than spun in at speed using a drill adapter. Capsules can be useful if placing the odd single bolt here and there, but remember that the performance is often poorer than for cartridge resin and you are also best using them when specified for a particular bolt.

Resins should include documentation giving a table showing the time for the resin to start setting (called the gel time) and the time to full strength, for a range of temperatures. This should include a minimum and maximum installation temperature. If the bolt is physically moved after the gel time, it will be loose and fail to reach full strength. This is also the maximum working time, as after this the mixer nozzle will become blocked and require replacing.

Replacing a blocked nozzle allows the remaining cartridge to be used, but this requires some care as sometimes one liquid component can get clogged up. A quick wipe with a rag before screwing on the replacement nozzle can fix this, but always repeat the step of discarding the first 10cm bead and keeping a sample whilst visually checking for a colour change before using the resin.

An important thing to note when using resins is that they have a relatively short use-by date, which will be written on the cartridge or capsule. In addition, cartridges should be stored upright before use, as otherwise air bubbles can mess up the mix ratio. Out of date resin can be useful for gluing on loose but crucial holds.

Appendices

A: Typical compressive strength data from rock quarried in the UK

Rock	Compressive strength range (MPa)
Granite	96-310
Gabbro	124-303
Dolerite	151-185
Basalt	110-338
Limestone	14-255
Sandstone (inc Millstone Grit), dry	34-248
Sandstone (inc Millstone Grit), wet	15-120
Gneiss	152-248
Quartzite	207-627
Slate (perpendicular to grain)	138-206
Slate (parallel to grain)	65-101
Standard concrete for EN959:2019	50

These figures are for quarried rock used in construction; it is therefore possible that the compressive strength of rock which you may wish to bolt is substantially lower than that quoted. The weakest recorded rock here is an Oolitic limestone, similar to that which forms the popular sport climbing crags on Portland!

Also of note is the ~50% reduction in strength for wet gritstone and sandstones, and the similar halving of strength for slates when tested parallel to the grain direction as opposed to perpendicularly.

B: Corrosion issues affecting rock anchors

The places in which rock anchors are placed can vary from fairly benign to fairly hostile environments. As a general principal metal parts exposed to moisture and air will corrode unless something is done to protect them, so some form of mitigation is necessary for long term installation. Protective surface coatings such as galvanising offer a low-cost solution, but unfortunately are fairly easily damaged and don’t provide long enough lasting protection.

Austenitic stainless steels or titanium alloys are better protected because they form an active or self-repairing coating formed from their own oxides. For this reason, AISI 304 grade stainless steel was the original benchmark material for outdoor use.

There are a few situations which can prevent the protective layer from reforming correctly in stainless steel, particularly in more hostile conditions such as when chloride ions are present, such as in seawater. Pitting corrosion and crevice corrosion are examples of localised corrosion caused by a breakdown of the oxide layer – both can cause total failure of parts whilst being difficult to spot. One counter is to use a grade of stainless steel with increased alloying elements present, which is why the AISI 316 grade stainless steel or its equivalent (often called “marine grade”) has become the minimum allowed in the latest EN rock anchor standard for outdoor use. In addition, anchor design and surface finishing such as passivating have a large part to play in preventing these corrosion types.

Galvanic corrosion occurs when metals with different corrosion potentials are mixed together. The addition of an electrolyte such as rain or seawater creates an electrochemical cell and leads to rapid oxidation of one of the metals. Historically this has occurred when galvanised steel bolts were installed with stainless steel hangers. The end result is a heavily corroded bolt with a nice shiny hanger which is a ticking bomb waiting to fail on somebody.

One final concern is the potential for stress corrosion cracking of stainless steel anchors including those made from AISI 316. Stress corrosion cracking (SCC) is caused by a triad of factors – warm temperature, ions from seawater or heavy industrial pollution, and material stress. SCC in rock anchors has been reported in many warm coastal locations including: Cayman Brac, Croatia, Dominican Republic, Madagascar, Sicily, Lanzarote, Menorca, and Thailand. It is also suspected as the cause of bolt failures reported in Malta, Morocco, Portugal and Greece.

Fortunately for us in the UK, there have been no reported or suspected cases of SCC, and the environmental conditions do not appear to favour its occurrence. Nevertheless, research monitoring is under progress in case environmental conditions change. Our current recommendation is to use class 2 anchors for outdoor use. At locations where there is a potential risk of SCC such as areas within the influence of the sea, use of class 2 anchors is acceptable with the understanding that if SCC failures are detected this may require a large-scale re-equipping programme using class 1 anchors. Installing class 1 anchors to begin with precludes this risk but at a substantial additional cost, therefore we leave this decision to the discretion of the installer. Information on the anchor classes is found in the table below.

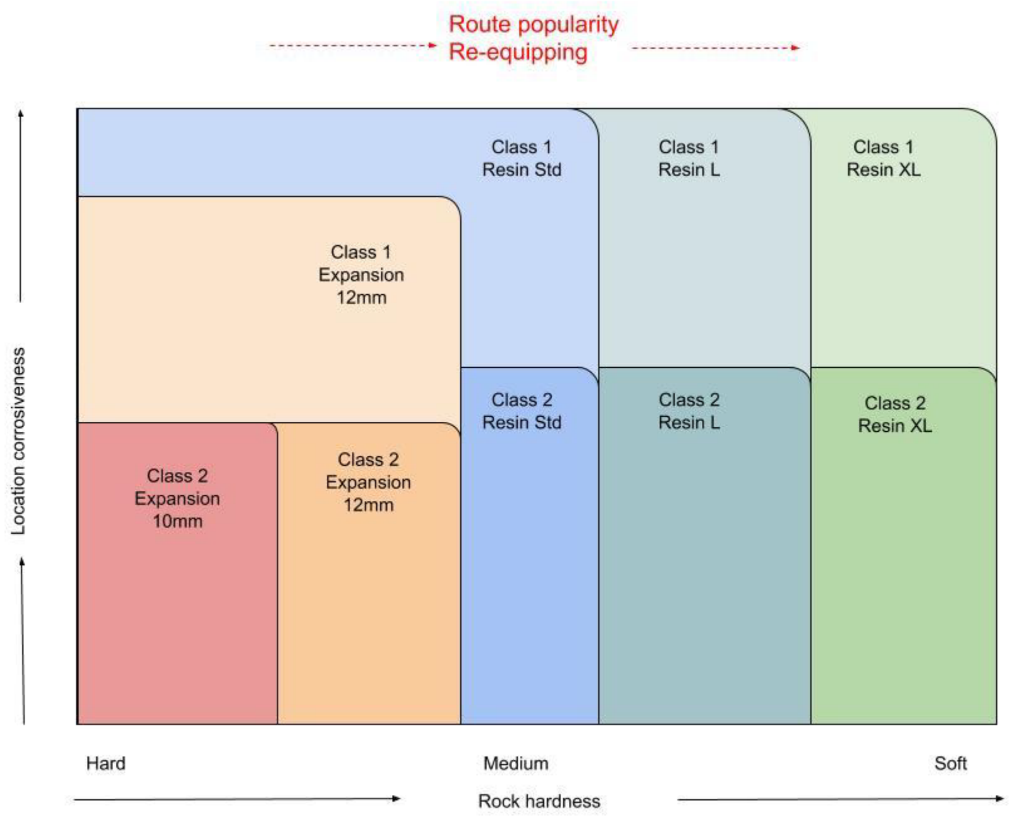
C: Anchor material class and suitable locations

Taken from EN959, locations and suitable materials are split into 3 classes, of which 2 are for outdoor usage.

Anchor class	Suitable for environment	Characteristics of environment	Specified materials	Comments
1	Aggressive stress-corrosion cracking (SCC) environment	SCC in evidence High chloride concentration Temperature above 30 °C Humidity (20 - 70)% Sea salts and salts from rock (limestone/dolomite) and/or high acidity (pollution, mineral leaching, rotting vegetation)	Titanium grade 2 3.7035 & Stainless steel 1.4565 1.4529 1.4547 1.4539	SCC is commonly associated with sea cliffs, but may also occur inland and at other locations, for example indoor swimming pools
2	Outdoor environment, not aggressive enough for SCC	No SCC in evidence and none suspected General corrosion agents present	1.4401 / 316 / A4 1.4404 / 316L 1.4435	1.4301 and 1.4306 (304 / A2 & 304L) steel not recommended for outdoor use
3	Indoor use, climbing gyms	No SCC in evidence and none suspected	Moderate protection from corrosion such as galvanised coatings on steel, anodised coatings on aluminium	Class 1 or 2 anchors may be required if the gym is located in an industrial area, by the sea or near to a swimming pool

D: Choosing an Anchor

General anchor choice can be summarised using this graphic below, where the Class relates to the material class given in Appendix C above. Resin bolts can be broadly categorised by their length: Standard (80mm-100mm), Long (120mm-150mm) and Extra-long (200mm+).



Specific recommendations are outside the scope of this guide but we aim to publish a survey of available anchors and belay sets including test result in the future.

E: Choosing Belays

Belay options assume you have chosen a suitable anchor as the basis of the belay. The main options are outlined below with commentary on their utility for different usages.

Resin belay anchors – a pair of resin anchors each with an enlarged eye. Simple, affordable and with the lowest visual impact. Any wear will require replacement of the anchor, so only suitable for unpopular and poorly frequented routes.

Expansion bolt with belay hanger – a pair of expansion anchors with a special belay hanger either made of shaped and welded cylindrical rod, or with a ring welded in place. These have a low visual impact and the ease of placement that expansion bolts provide.

Photo: Expansion bolts with belay hangers

Rings and maillons – the simplest way to convert a twin bolt belay into one which has easily replaceable parts. Rings last a long time because wear is evenly spread, as long as they are free to rotate. Availability is limited to AISI 316 material (class 2), with care needed to ensure parts meet the 25kN requirement in EN959. Best sourced from a bolt manufacturer although there are some very nicely made rings available from marine fabricators and suppliers.

Photo: Maillon and ring make a durable belay option

Chain belay sets - available in two basic layouts. V-shape are equalised but are the most expensive option. L-shape are cheaper and although not equalised (the top bolt is not loaded) this shouldn't be an issue unless the primary anchor fails. Options available in AISI 316 and other materials including some class 1 such as Titanium.

Photo: Chain belay sets with a ram's horn lower off below

Further options – belay bolts and rings all have one major downside. They require the rope to be untied and rethreaded, which if done incorrectly can result in serious injury or death. For this reason, some installers may choose to opt for a different attachment system where rethreading is not required. These include ram's horns and karabiners, and can be used both on pairs of bolts or instead of the ring on a chain belay set. Whilst safer in principle, they still require training and experience to be used correctly and will not prepare a novice for when they travel elsewhere where they need to rethread.

REFERENCES

[1] BS EN959:2018 Mountaineering equipment. Rock anchors. Safety requirements and test methods

[2] Bolts: A climber's guide. BMC online publication

MANUFACTURERS

Bolt Products   Petzl   Raumer   Titan Climbing

ADDITIONAL INFORMATION

BMC Research report: Anchor testing

BMC Research report: Seacliff anchor testing

UIAA Safety Standards