



**British
Mountaineering
Council**

Bolt Guidance Document

Part 2: An Installers Guide

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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.

DISCLAIMER

Neither the BMC nor the authors of this document accept any liability for the death of or injury to any person involved in bolt-protected climbing arising from equipment failure or otherwise or to any person involved in placing bolts and against whom such a claim has been made.

The purpose of this document is NOT to give definitive advice on what fixed equipment should be used or how it should be used. The great variation in rock types and condition, climate and environment render that impossible. Rather it is to alert the climbing public to those potential problems and risks that have been identified. Climbers must rely upon their own experience. Climbing is dangerous: it can damage your health.

SYNOPSIS

This work comes in two parts and is intended to increase the climber's knowledge of how these devices work. The first part is intended for users of bolts and the second is for those who place them, although both sections may well be of interest to all.

Part one contains information on the history of bolts, types of bolts likely to be encountered and problems to watch out for. The second section has more technical information on the choice and installation of equipment. It also examines the legal implications of placing bolts.

Please note that neither is an instruction manual. They are intended to be informative documents for those who wish to clip and go.

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It is assumed you have read Part 1: The Users Guide and have a good understanding of all of the issues identified there.

INTRODUCTION

These documents have been produced by the BMC Bolts Working Group. This group brought together scientific expertise from chemists, mechanical engineers, metallurgists and geologists along with many years of practical experience from climbers who have placed bolts and, perhaps more importantly, examined old bolts during the process of replacement.

The aim of the project was to increase the knowledge base of the climbing population and to examine current practice. It comments on methods and materials to ensure that safety issues are clearly understood and available to activists involved in placing new, and replacing old, bolts on British cliffs.

We hope these documents will be useful in influencing the thinking and decision making of those about to embark on bolt-protected climbs, about to commit to an irreversible move above a rusting fixed relic of doubtful origin, or those who may contemplate placing bolts or pegs in the future.

In making recommendations we have suggested the systems that we consider to be the most appropriate. We have done this with the interest of the future of bolt-protected climbing in mind and to encourage thoughtful replacement as old gear becomes in need of renewal.

The term 'bolt' generally refers to any form of metal placement that requires a hole to be created unless otherwise stated. The term 'glue' includes all forms of chemical resins, adhesives and cements.

CONSERVATION

Most crags are legally protected for conservation reasons and Natural England have a statutory duty to protect all SSSI and SAC designated sites from damage. Quite severe penalties prescribed under the Wildlife and Countryside Act (1981) and Schedule 12 of the Countryside and Rights of Way Act (2000) could be inflicted upon anyone found to have broken the law.

Where the protected species is a bird this may be fairly apparent, but in the case of small plants such as lichens, bryophytes and rare grasses, identifying protected species can require specialist knowledge. All climbers need to bear in mind that the legal onus is on them to find out what is present before equipping a new line.



Horseshoe Quarry, Peak District. This quarry is part of a SSSI.

In recent years, many crags have been acquired by Wildlife Trusts with the express intention of preserving and protecting the special ecological or geological interest. Most of the Trusts are reluctant to endorse new-route activities. You may feel this is unfair if you have your eye on a great new line, but ignoring any agreements between the landowner and the BMC could jeopardise all climbing, and not just that new route. Incidentally, this concern is also relevant to abseil descents.

The great majority of sport climbers are happy to stop where the good rock ends – before the loose and unpleasant stuff - and a well positioned lower-off can protect rare ledge soils and cliff top vegetation from damage.

In many cases, climbers do not have a legal right to access land unless it is mapped as Open Access land under the CroW Act. Where permanent fixtures are left as evidence of climbing activity, such as old slings or new bolts, then hackles can be raised. The reaction of landowners is not uniform, some are completely at ease with climbing on their land, and others can be very unsupportive. Anyone considering a new route, or rebolting an existing one, is advised to first contact your local BMC access rep - it may save you a considerable amount of time, effort, and money. In addition, the BMC Regional Access Database (RAD) gives the most up to date information of crags with special access and conservation considerations.

CHOICE OF ANCHOR & INSTALLATION ADVICE

If you are considering placing rather than simply using bolts, the following guidance will be useful. It is wise to prepare carefully and know that you have chosen the correct equipment and know how it should be installed. Seek advice from manufacturers where necessary. The following sections lists things you should consider:

Any bolting system chosen will fall into one of 3 categories, whether it is a mechanical or glue-in bolt.

1. Rock Anchors for Mountaineering, EN959



Fixed glue-in and Petzl mechanical bolts, manufactured to the EN 959 standard.

As long as the manufacturers installation instructions are followed, you can rely on the fact that the bolt has been tested and approved to the required standard for climbing and that a quality control system is in place to ensure that defects are rare. Unfortunately such bolts are invariably more expensive than other types, and may not always be ideal for a specific situation.

2. Industrial Fixings



Fixer hanger, mounted on a commercially sourced industrial expansion bolt.

There are industrial fixings available, both mechanical and glue-in, which may be suitable for use in climbing. Because they are not specifically tested for this purpose, the onus is on the installer to correctly specify their requirements when ordering from their supplier. This does incur extra responsibilities on the installer. For instance, some bolts may have the required shear strength, but are not designed for dynamic loading.

3. Homemade Bolts

A wide variety of home made bolts have been used in UK climbing. These have come into use when the alternatives have either been too expensive, of limited availability, or are unsuitable. Whilst the BMC does not seek to condemn nor criticise homemade bolts already in use, we do urge anyone contemplating making such items in the future to consider seriously the advice, warnings and technical information contained in this document.



A homemade lower off at Horseshoe Quarry.

Subjecting your product to pull tests to reassure yourself of their capacity to withstand repeated falls as in the proposed revision to the European standard would be a good idea. The BMC may be able to assist with this. Despite these reservations, the overall record of these bolts is very good with very few reported failures, with many of these due to defects which have since been designed out.

The choice of bolt can be a crucial decision. For mechanical bolts a 10mm minimum has become accepted across Europe. The smaller diameter hole requires only 1/3rd of the volume of rock to be excavated when compared to an 'eco' style bolt of similar depth. This makes drilling the hole much quicker, less strenuous in difficult positions and uses less battery power.

Where there is significant fracturing in the rock or the rock is soft or poorly cemented, the use of glue-ins should be considered, since they do not apply a force to the rock until loaded, and spread the load over a wider area. Soft sandstones have been shown to be particularly unsuitable for mechanical bolts.

For corrosive environments, such as sea cliffs, glue-in bolts are a good option. Corrosion is reduced by not having gaps between parts, which otherwise can lead to crevice corrosion.

Mechanical Bolts

Self-Drilling Anchors



Petzl 8mm self-drilling anchor.

The anchor is placed onto a device called the driver, which enables it to be hammered into the rock. By modern standards these anchors are weak even when placed in hard rock such as granite.

The Through Bolt



Petzl 10mm through bolt.

A hole is drilled to the required depth and the anchor hammered, complete with attached hanger, washer and nut, into the hole. Tightening the nut draws the tapered end of the bolt into the metal collar causing it to expand. Once the nut has been tightened (never over-tighten it) the unit is ready for use. From a conservation point of view it is good practice to drill the hole deep enough so the bolt can be hammered into the rock when, in future years, it corrodes, as once expanded they cannot be easily extracted. However, never knock the bolt back into the rock and retighten it, as the unit is then likely to be unsafe.

The Sleeve Anchor



Sleeve anchor with a Petzl hanger.

A hole is drilled to the correct diameter and depth and the bolt tapped into the hole complete with hanger. Expansion of the sleeve is then achieved by turning the nut, which then draws the sleeve over the tapered end of the threaded bolt. This gradually tightens until the nut is locked against the washer and the unit is secure. This type usually requires the hole to be thoroughly clean to enable the tapered end to bite.

Glue In Bolts

The Staple



Home made staple anchor.

To place the staple, two perpendicular holes are drilled. The legs of the “U” should fit so that only the bend is visible. Dust and debris in the holes should be cleaned and blown out at least 3 times. Glue is then squeezed into the hole as soon as possible after drilling so that dampness cannot set in and then the staple is inserted into the holes. Any excess glue can then be wiped away from the area.

The glue should then be allowed to set thoroughly for the time recommended by the glue manufacturer (depending on the glue type and the temperature) before the route can be climbed.

The DMM Eco Anchor



DMM Eco anchor.

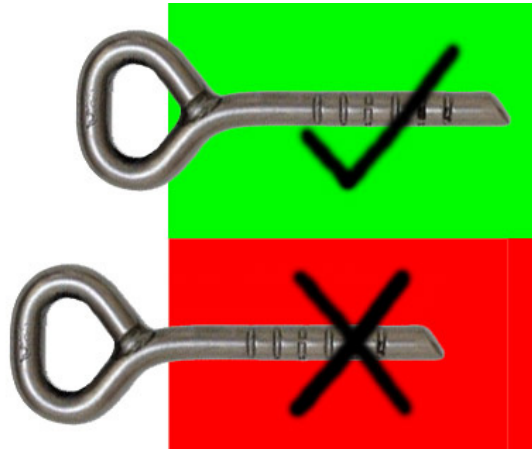
The placement is less complex than the Staple and requires a single 18mm hole to the appropriate depth. The hole should then be cleaned as in the case of the staple and the glue applied in the same manner.

Eyebolts



A selection of eyebolt anchor types.

A wide range of glue-in eyebolts is available. An example is the Fixe eyebolt, where a 12mm diameter hole is drilled to the required depth for this 10mm bolt, which leaves enough room for the resin. Either an ampoule or cartridge gun system for the resin can be used. To prevent rotation of the eye, which may fracture the resin bond, it is important to recess the eye by drilling a groove as shown below. This also acts to reduce bending forces on the eye.



Recessing the eye to prevent rotation and bending.

Glue-in Threaded bar



Glue-in threaded bar anchor, with a Fixe hanger.

Threaded bar needs to be treated with a degreaser to get the required bond with the resin. There are complications because of the need to torque the nut on afterwards, when the resin has set, however this can easily be avoided by using a nylock nut which is pre-positioned on the threaded bar. It is very important that the threaded bar is cut with a wedged end to prevent it turning on its threads. Commercially available industrial fixings of this type are available, which remove the issues concerned with using home made equipment.

Place Well And To Last

Stainless steel bolts and appropriate glues can be expensive. However, if you are going to install a bolt then it makes sense to ensure it lasts and prevent rock damage due to frequent renewal. **We would suggest that all components of bolts are made of stainless steels taking note of the points made about corrosion in the Appendix.** Similarly, when purchasing glue it should not only conform to other requirements listed in this booklet but also have an appropriate life once hardened.

General Installation Advice

Placing bolts can be relatively easy once a system has been worked out but it can also be a strenuous and time-consuming process. Clearly the use of power tools, chemicals and other devices in close proximity to nylon ropes on, often overhanging, rock faces requires more than a little thought and you might wish to get some instruction before taking on a project. Proficient use of abseil and/or ascender equipment is a pre-requisite for your safety.

On slabby or vertical faces, so long as the rope is in line with the route, it is fairly simple to access the proposed installation sites. On overhanging faces it is possible, using mechanical bolts, to start at the top and clip the rope into each bolt placed as you descend, meaning you stay within reach of the rock. However, if glue-in bolts are to be used, they require long setting times and you may have to consider some sacrificial mechanicals and/or a low placed bolt through which the rope can be clipped and a helper can pull you in towards the rock. Even so you will often find yourself having to handle the drill one-handed whilst using some feature with the other to hold yourself in position whilst you drill the hole. Usually at least two descents, one to drill and clean the holes, the second to glue, will be required.

Attention must always be given to following the manufacturers installation instructions and these will usually require you to prepare the hole with care and install the bolt using a number of tools. Care must always be taken to ensure the hole has the correct depth and angle that allows the bolt and hanger to sit properly in and against the rock and that any further preparation (like cleaning out the dust) is done correctly.

Standards

The proposed revision to the European Standard for Rock Anchors (prEN959) suggest that the installed length (i.e. the part in the rock) should be a minimum of 70mm for glued anchors and for mechanical anchors at least 5 times the diameter of the drilled hole. Once installed all bolts should, in a concrete block (minimum size 200mm cube and compressive strength of 50 Newton's per square millimetre), be capable of withstanding an outward (axial) pull of 15kN and a downwards (radial) pull of 25kN, this after having previously withstood 10 x 8kN loadings.

It may be that in the event of a bolt failing it would be difficult for any person or organisation installing bolts of a lower specification to justify their choice. If you place bolts you should aim for the same holding forces. If the rock is softer than the prescribed concrete (something that is highly likely) then longer (and/or wider) bolts may be needed.

As has been stated elsewhere in this document we feel that all anchors and all other metal components should be made from the same grade of stainless steel (either AISI 304 or, especially in a coastal environment, AISI 316 or their EN equivalent) that will give a significantly longer useful life if used on British crags.

Rock Considerations



Cracked rock around this lower off could cause problems.

Bolts should, where possible, be installed in rock that is sound and not where there are fissures running behind it. To judge if the rock is sound, gently tap the rock with a hammer and listen for resonance. A dull thud or hollow sound might indicate that the proposed installation site harbours unobvious fractures and is potentially unsafe. The degree of resonance that is acceptable is a matter of judgement and any installation in rock will always be subject to some doubt.

You should seek to minimise this doubt and consideration may be given to the best possible placement and not merely a position chosen purely for ease of clipping. It is sensible that any inexperienced installer experiments in some unobtrusive location and gets a feel for the range of pitch that indicates loose and sound rock.

Due to the possibility of rock fracture, any placements, even in the soundest rock, should ideally be a **minimum** of 200mm away from an edge, fracture line or other bolt. In real-life situations, this is often impossible to achieve.



The bolts on this route are good, but how long will the route itself be there for?

Sustainable Bolting

With the relatively small amounts of rock available to climb on in the UK, we should consider it to be a precious and finite resource. Think about the future. Can the bolts you place be easily removed, or will they end up scarring the rock forever? Is it possible to re-use the original drilled holes when re-equipping? In an ideal world, we would re-use the same boltholes over and over, with the added benefit of maintaining the character and grade of the routes; moving a bolt by a foot may make it a totally different proposition. If the nature of the crag is fairly broken and shattered, existing bolt placements may be the only solid place available for replacements.

Care should be taken to mitigate the visual and aesthetic impact of fixings. Hangers should ideally be of a colour that naturally blends into the rock. In some areas e.g. Chee Dale, the landowners' preference is for staples, which are perceived to be less visually intrusive.

Spacing

The distance between bolts is a matter of choice but a number of considerations should be taken into account. Near to the ground (or any significant ledge or slab encountered en-route) the possibility of a ground fall should be considered and the first two or three bolts should be fairly close together. If there is doubt about the security of a placement the consequences of its failure should also be considered and the bolts may need to be closer together. Getting the spacing correct is an art. You might wish to consider top roping the route first to get a feel for where the bolts should go.

Belays and Lower-off Points



Chain linked lower off with welded ring.

Installing lower-offs and belays depends very much on the quality and local topography of the rock at the desired point. Ideally a belay or lower off should consist of two anchors placed in good quality rock, positioned for ease of attachment rather than as close to the top of the crag as possible. If the rock is at all suspect or seamed with cracks it is sensible to place the two anchors in separate blocks, even if this means they are further apart than the distances suggested below.

There are several popular methods and perhaps the best, mechanically, is to have two bolts around 300mm apart linked by two short lengths of toughened chain to a fixed welded ring. Various configurations of this simple system can be bought as one unit from specialist suppliers but are relatively expensive. A single point lower off avoids putting kinks in the rope, which can be a problem with twin point lower offs. Hybrid do-it-yourself versions will be found on many crags but invariably the separate components are of dissimilar metals and corrosion quickly results.

Note: *fixed screw gate karabiners are not recommended for outdoor use as they invariably seize up, even stainless steel varieties. Rings are a better option.*



Alloy and steel krabs quickly become useless.

A useful but cheaper option is to place two glue-in bolts 200-300mm apart, one higher than the other to reduce kinking of the rope. The eyes of most common glue-in bolts are big enough to thread a bight of the rope whilst also loaded with a karabiner and quick-draw. The rope should only need to be threaded and untied by the last member of the party and all other descents and or top rope ascents should be made through leader placed quick-draws to avoid excessive wear on the eyes of the bolts.

An even simpler method is to install two standard through bolts, one slightly higher than the other as above, and then attach hangers equipped with welded rings. These are used exactly as described above but the welded ring, being mobile within the hanger, is less likely to wear in the same place. If it does so, on very popular routes, it is simple and cheap to replace onto the same bolt stud. Another alternative is to use standard hangers with stainless steel Maillon Rapides attached.

On routes that are other than close to vertical consideration should be given to the line of descent from the chosen lower-off position. Try to avoid areas of loose rock or vegetation and remember that in many cases the leader will wish to retrieve his/her quick draws from the route during the descent. This may, of course, not always be feasible and the route may need to be seconded.

On multi pitch routes a bolt should always be placed within a metre or so above the belay to minimise the risk of factor 2 falls. Even where expense is not a consideration and chain type belays are available the installer may need to consider environmental issues. These units are certainly more visible than simple double glue-ins or rings. It may be that ease of use and convenience has to be sacrificed in some sensitive locations to minimise the visual impact on the environment.

Glue & Glue-ins

No specific glue type or chemistry is recommended in this document, since it is not the place of the BMC to recommend commercial products and more importantly, there is a bewildering selection currently available [epoxy, methacrylate, urethane, etc and all combinations], plus a new one may become available tomorrow. An appropriate glue will usually be a product that needs to be sourced from an industrial supplier, who can advise you on the products that will best meet your requirements.

Before gluing, it is essential that the drilled hole is free of debris and dust. Inadequate cleaning will result in a poor bond between the resin and the rock, which can dramatically reduce the pull out strength of the bolt. Thorough cleaning with a hole cleaning brush should be followed by blowing out with a blower pump, with this process repeated at least 3 times.

Use a glue which is specified for, or with a good history of use in, rock anchor applications, either in civil engineering or as part of a commercial bolt-plus-glue kit (e.g. Petzl Collinox + Ampoule) and not one bought off the shelf of your local DIY store. The latter may be cheaper, but may lead to serious problems to you or to others repeating your route. The story of glue-ins failing after only two years by adhesive degradation, might have been as a result of a polyester DIY glue being used, since there is industrial experience of polyester not being resistant to strongly alkaline ground waters, e.g. as found percolating through wet concrete, and wet limestone may be less alkaline, but still sufficient to accelerate decomposition

Glues need handling and using with care – always following the manufacturers instructions. The types used for bolts usually come in a unit with two sealed tubes. This needs a specified gun, which is matched to the glue cartridge and which bursts both tubes simultaneously, then extrudes the contents out into a static mixer head. The mixer head is also matched to the glue and is a removable nozzle with an internal structure that ensures complete mixing. Serious accidents can happen if the two parts that make up the compound don't properly mix as the resulting paste will remain as just that and not harden. It has been known for one tube to burst but the other to remain intact inside the gun. A small amount should always be discarded from a new nozzle, as the first part will not have mixed properly.

Once happy with the mix, but before use in the bolt holes, a test sample should be kept and inspected later to ensure that hardening has taken place.

Care should be taken to place enough glue in the hole. The anchor should be inserted with a 360-degree twist to ensure all of the keying features are in contact with the glue (due to the need for two holes the described twist cannot be achieved with staples). A small amount should extrude and any excess carefully removed with a cloth.

Some bolts are fixed by drilling a hole to a specified depth and diameter, inserting a sealed ampoule of glue (that contains separate compartments containing the two compounds, the resin and its hardener) and then the bolt. These are particularly useful if only one or two bolts are being placed. It is essential for the hole dimensions to be correct; otherwise there may not be enough resin to form a decent bond. Some manufacturers' instructions indicate that their glue requires the bolt to be placed in the drill chuck, the ampoule broken, and the glue vigorously mixed by the multiple turns resulting from a quick pull in the trigger. With some bolts this cannot be achieved so can only be done by hand. For one commonly used glue, *at least* 25 turns will be needed – the more the better but you need to check the manufacturers instructions. Care should also be taken that the ampoule itself is broken into small pieces. Volumes and mix ratios are critical with these glues, so never mix components from different suppliers.

Glue manufacturers usually specify the diameter of hole, which is required for a certain diameter bar. For 10 mm diameter bar the specified hole is often 12mm but this does vary from glue to glue. It is important you get this right as too much or too little glue can result in a weaker placement. In some tests bolts placed with an interference fit i.e. a 12mm bolt in a 12mm hole, were found to be poorly bonded, whereas too big a hole and the resin may not cure properly.

For correct curing, some glues need to achieve a minimum temperature, the heat being produced by the chemical reaction they undergo as they cure. Placing a large piece of metal (that acts as an excellent conductor) into the glue means much of the heat is not retained and the glue can fail to achieve the required temperature.

Therefore this type of glue may be unsuitable if used when bolting on a 'too cold to climb' winters day. Other glues need a combination of time and/or elevated temperature to react until completely cured, i.e. a longer time at lower temperature, or vice versa. For this glue type, any conducting metal in contact will only alter the time to achieve cure, not prevent it. Therefore this glue can be used on a cold bolting day, but the time to cure may be longer than that quoted by the manufacturer, for more ideal conditions

Most glues require dry conditions to maximise adhesion to the rock and to the steel, therefore glue-ins should always be placed in dry rock. One study showed that the pullout strength was reduced by 27% in damp holes and 57% in wet ones. A special glue may be available, if wet conditions are unavoidable.

As always, read the manufacturers instructions, because glues specified for use with bolts or for outdoor application will have already considered all these issues.

If glue-in bolts are placed and the installer has to leave the crag before the curing time has elapsed it is a good idea to leave a note indicating that the bolts haven't been checked.

Mechanical bolt installation

Mechanical bolts come in a range of types, lengths and thickness as described above. As stated earlier, across Europe a minimum diameter of 10mm for single leg bolts has become the accepted norm when used in climbing situations but there is no guarantee that these diameters will be sufficiently strong in all situations. With through bolts a minimum length of 80mm is suggested for good, solid rock but longer shafts (90–120mm) should be considered if the rock is soft or otherwise less than ideal.

When tightening mechanical bolts (or placing hangers on glued studs) they should be neither under or over-tightened. A bolt which cannot achieve the recommended torque figure is one which has not gripped, either due to dust in the hole, incorrect hole diameter, or too soft rock, and will not withstand the rated load. Over tightening will permanently damage and weaken the bolt.

Hangers should lie flat against the rock. They should be secure as, where they become loose, wear on the bolt can give rise to serious weakening. For most hangers the point at which the karabiner touches the eye should be directly below the centre of the bolt. If the bolt has to be inserted on an overhanging wall (and is therefore off-vertical) a pull will result in leverage on the hanger. For some hanger shapes, placing them upside-down brings the karabiner closer to the bolt and so creates less leverage **but this probably contravenes the manufacturers recommendations.**

HOME MADE BOLTS

If you make bolts in your garage it is unlikely they are being manufactured or tested to any recognised industrial strength or safety standards nor complying with the European standard for rock anchors. Because of this their safety and integrity cannot be guaranteed. In the event of an accident due to failure it is possible that any subsequent legal claim could be more difficult to defend. This is the same for any other type of homemade fixture left in place for subsequent ascents by others.

Hangers

Various types of bolt hanger have been homemade (EN 959 also describes the requirements for hangers) sometimes from inappropriate materials such as aluminium.

“As he pulled off the ledge (Malham Halfway Ledge) the hanger on the second bolt simply ripped and so did the one on the first. With so much rope out it was a spectacular fall – hitting the ledge and leaving him hanging over the lower wall. Fortunately the tree provided a stout belay.”



A homemade hanger at Horseshoe Quarry.

U Bolts or Staples

As already mentioned, modern home-made bolts, in recent years, have generally taken the form of U shaped staples with bent or notched legs to give a mechanical 'lock' when held in parallel holes by glue. These have become very popular at some UK venues where they are regarded as the most practical solution, particularly Portland, where they are now accepted as the bolt of choice. They have usually been manufactured from stainless steel bar and over the last 15 years or so, seem to have withstood the test of time very well, supporting thousands of ascents, with no recently reported failures.

There are criticisms of U-shaped staples, based on a number of tests around the world, some of which support them and others that don't. It would be remiss of us not to mention them. The problem is that there has been no standard manufacturing process so that; leg length, bend, separation, notching, the glue used, rock type and a number of other variables make comparison almost impossible.

Listed below are some of the concerns and counter claims regarding staples:

They are commonly used as a solution to soft rock situations. In soft rocks there is however a danger of them pulling out due to rock failure by the increased risk of radial stress cracking caused when two holes are drilled in close proximity. The closer the holes the greater this will be. A counter claim is that, though each leg may be weaker than a single bar, together they may add up to a much stronger placement (If both legs have only 75% holding capacity of a single bar, combined that would be 150%)

Increasing the radius of the bend, keeping the legs/holes further apart, reduces this problem but certain separations can increase the potential for karabiners to unclip from the bolt when lifted by the rope. When used as belay points it is important that the radius allows for a krab and the rope to go through easily so that setting up a lower off doesn't require unclipping from either staple before the rope is threaded.

The force required to pull the staple horizontally out is very low **if** the legs are parallel and smooth since there will be no mechanical key. A common way of reducing the problem is to put a bend (approximately 15 degrees) in the leg. One set of tests showed that a lot of notches needed to be cut to gain a good key (care must be taken to not weaken the leg with too many notches). Roughening the bar by grinding it also improved the hold. Deep (approx 1mm) threads formed a much better key than notching and grinding, shallow (0.3mm) threads were, understandably, much worse. The key variable seems to be the volume of glue that is keying the staple.



This early version of a staple pulled out at a very low load. Without notching or filing there was nothing for the glue to key onto.

Because the bolt can't be turned through 360 degrees as it is inserted and due to the viscosity of the glue it may not always flow into the notches. If little glue flows into the notches (or if there are insufficient notches) then the keying effect would be reduced. It is possible that threads gain a better key because the glue can enter the grooves more easily. Filling the notches with glue by spreading it over the legs before insertion may overcome the problem.

Bent legs have been said to push the glue out of the way as they go into the hole causing voids and reducing the strength of the device. A bent leg also requires a wider diameter hole and therefore increases the volume of glue and the metal to rock distance. Installers should check that this is within the specifications for which the glue is suitable.

Dependent on the properties of the steel bar used the process of bending to form the staple may cause some weakness. None so far have shown signs of this but that may be because the appropriate alloys have been chosen.

Please note: *The Bolts Working Group are not seeking to imply that staples already in place are unsafe only that, as with all home-made equipment their integrity can not be guaranteed or be as readily assumed as in the case of industrially produced and tested bolts of other types. It may be worth keeping an eye on the climbing press for any further developments.*

Glue-in Threaded Bar

Other home-made bolts that have achieved some popularity due to their simplicity and cheapness involve gluing in sections of threaded bar upon which a hanger and nut are attached. This system has been said to work so long as stainless steel bar of at least M10 x 80mm with a deep thread (see above) is used in an appropriate diameter hole with the correct glue. The bar can be twisted into position. If the end of the bar is cut diagonally this prevents the fixing from rotating out of the glue after setting.

The downside of this system is the setting time required before the nut can be tightened and the torque probably needs to be more precise than on through bolts. There is also a misconception propounded that non-stainless steel bar is protected from corrosion in this method because of being sealed in the glue. This is not the case and the exposed sawn end of the bar is particularly vulnerable and, of course the main stress point on the bar is close to this end beneath the hanger.

KEEPING RECORDS

In our increasingly litigious society being able to justify your actions in the case of legal claim is most important. If you place a bolt that subsequently fails, causing injury to a climber, the possibility of that climber making a claim against you cannot be excluded. Of course if you act responsibly and reasonably, using your best judgement and experience of the most appropriate techniques and materials then you can argue that you have no liability.

In the case of a bolt failure due to metal failure and/or corrosion, faulty placement, or rock failure resulting in a legal claim defence lawyers, however, are quite entitled to question you closely on the techniques and materials used. If you were unable to justify why you placed an M10 x 80mm through bolt rather than a 120mm glue-in then your case could be in jeopardy. Perhaps even worse in the case of court action would be to claim you couldn't remember what you placed – or why.

The BMC suggest that at the very least, first ascensionists should keep detailed records of the type and size of bolts placed and type of glue used on all new routes. Similarly groups or individuals involved in replacing old equipment should keep similar records. Specifically in the case of glues, batch numbers supplied on the tube would probably be most useful.

Guidebook first ascent lists give a good idea of when the original bolts were placed on a climb and in the absence of any central database it may well be a good idea to consider recording the date of replacement as a by-line to the first ascent in future guides. Even if not needed for legal argument the information may be useful to influence the judgement of, and/or give some reassurance to, climbers setting out on a route which otherwise may contain bolts of doubtful origin.

Bolting Record: Example

Date	Route	Crag	Number placed	Type	Source	Notes
8/6/06	Big Route	Big Crag	14	Through M10 (80 – 120mm) 12 Fixe Hangers. 2 Rings	Central Bolt Supplies, Newtown.	1 misplaced bolt left with no hanger

APPENDIX:

METALS & CORROSION



Eco anchor placed in a drainage line

It is a pity that nothing lasts forever. This is as true of metals as it is of other substances. Before purchasing/making any bolts you may find the following information gives you an indication of how long they may last in different environments and what may be best to buy.

Corrosion can be defined as the destruction or deterioration of a material because of reactions with its environment. Below is a brief summary of the corrosion resistance properties of the currently used groups of metals (in descending order of effectiveness):

Stainless steel

These steels are the most corrosion resistant of the materials commonly used to manufacture bolts. Stainless steels (austenitic stainless steels) derive their corrosion resistance from a very thin, invisible surface (passive) layer which is formed during a reaction between the metal and oxygen (e.g. air) and forms spontaneously in air even if the surface is damaged by i.e. scratches. This oxide layer drastically reduces the corrosion rate of the material and the material is considered to be passive. Even though the passive layer slowly dissolves it is rebuilt again by oxidation (corrosion) of the underlying material. The oxide layer consists mainly of chromium oxide therefore stainless steels contain at least 10.5wt% chromium.

Two grades of stainless steels are commonly used for rock anchors: 304 and 316. (These designations are from the American AISI series of standards but have become generic terms.) Grade 316 differs from grade 304 in that it contains at least 2.0% molybdenum, which increases the resistance to pitting corrosion. The European equivalents of grades 304 and 316 are 1.4307 and 1.4432 respectively (specified in BS EN ISO 10088). To complicate matters further, stainless steel fasteners are specified in BS EN ISO 3506 with the equivalent grades to 304 and 316 being A2 and A4 respectively. The suitability of the various grades for use at coastal and inland locations is shown in Table 1. Table 2 shows the full composition of these metals for those who are curious.

Galvanised/Zinc Plated Steel

Both galvanising and plating coat the surface of the steel with a layer of zinc. In galvanising, the steel is dipped in molten zinc whereas in electroplating the steel is submerged in an aqueous solution containing a zinc compound and the zinc is plated on the surface by passing an electrical current across the bath. An undamaged piece of galvanized steel will corrode at the same rate as a similar piece of zinc. Once the zinc coating is perforated (by mechanical damage, for example), the zinc forms a galvanic couple with the steel (see also galvanic corrosion), and the zinc corrodes preferentially to the underlying steel hence protecting the steel, prolonging its life. The zinc will continue to protect the steel until most of the zinc coating is gone. Once the zinc coating has disappeared, you may begin to see a lot of thin patches of rust as the steel starts to corrode.

Therefore the effectiveness of galvanising/electroplating is proportional to the thickness of the zinc layer. Of the two processes galvanising tends to give better corrosion resistance and electroplating higher strength steels can cause cracking.

Carbon-Manganese Steels and Alloy Steels

These materials can be strong and relatively cheap. In the case of the alloy steels used for bolts and hangers the alloying additions are made to improve the mechanical properties (strength and toughness) and not the corrosion resistance. For this reason both of these groups of metals can be considered as having similar corrosion resistance. These steels will readily corrode, usually uniformly in the presence of oxygen and water to form rust. Unlike stainless steels, the oxides formed during corrosion aren't protective and the steel will continue to corrode.

Aluminium alloys

Aluminium is a reactive metal but it develops a tenacious oxide film in air, similar to stainless steels. This thin film is normally protective but chlorides readily attack it. Although aluminium is relatively weak, it can be strengthened by alloying to give tensile strengths approaching that of austenitic stainless steel, e.g. the stem of a rigid Friend.

Unfortunately, the most effective element for strengthening aluminium is copper, which also results in a decrease in corrosion resistance. Corrosion usually takes the form of pitting or exfoliation, which can drastically reduce the strength of the metal. For this reason, aluminium alloys are not recommended for hangers.



Aluminium hanger, steel bolt.

As far as the environment is concerned, all of the corrosion that occurs to rock anchors requires water (aqueous corrosion); this could be atmospheric, freshwater and/or seawater.

Atmospheric

Corrosion is primarily due to moisture/humidity and oxygen (air) but can be exacerbated by contaminants such as sulphur compounds (from pollution) and salt. For corrosion to occur in this environment the rock anchor doesn't have to be dripping wet, a very thin adsorbed film of moisture on the surface is all that's required.

Freshwater

The corrosivity of freshwater (rain) depends on the oxygen, sulphur and chloride content. This can come into contact with bolts as run-off or seepage and can be acidic (pH < 7), from peaty soils above crags, or alkaline (pH > 7), from ground water seepage through limestone rocks.

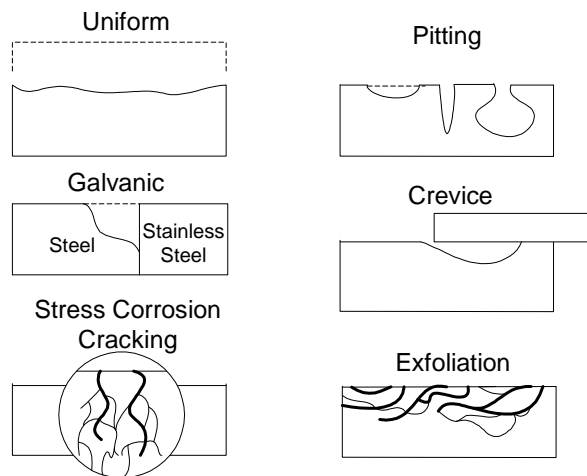
Seawater

Seawater contains about 3.4% salt and is the most aggressive environment to which rock anchors are subjected.

Because the corrosivity of seawater increases with increasing oxygen and salt content, the bolts in the splash zone i.e. the first ones to be clipped on some routes, are the worst affected, but there can be a considerable effect for up to a few kilometres inland. In the splash zone, the bolts can get sporadically wet by seawater spray, which can evaporate, leaving a salt layer on the surface. Further wetting and evaporations leads to the accumulation of salt hence increasing the aggressiveness of the seawater locally. Further inland, the moisture from the sea is transported by air/wind causing similar but less aggressive corrosive environments.

Types of Corrosion

In the environments where bolts are used, the following types of corrosion can occur:



Uniform corrosion

The metal corrodes and thins evenly until it fails. This form of corrosion gives the greatest metal loss but is the easiest to see and corrosion rates are predictable. Uniform corrosion is most commonly seen as rust on uncoated steel items or galvanised fixtures once the zinc coating has disappeared.

Galvanic corrosion

This occurs when two dissimilar metals are used together e.g. a mild steel bolt and a stainless steel hanger. The water acts as an electrolyte (solution containing salts which is electrically conductive, e.g. water) and a wet cell battery is formed. The corrosion rate of the less resistant metal increases and that of the more resistant metal decreases.

In the example mentioned, the portion of the bolt nearest to the hanger would corrode and the hanger would hardly be affected. Again, the effect of this type of corrosion is easy to see. As seawater is more conductive than freshwater, this type of corrosion is worst in coastal areas.



Stainless steel hanger, mild steel bolt

Pitting corrosion

Pitting corrosion is a localised form of attack and, as the name suggests, it takes the form of pits. If the pits are small and isolated they shouldn't have too great an effect on the strength of the item but if they're large, numerous and closely grouped they can significantly weaken the metal. Pits often look small at the surface but may have larger areas deeper inside the metal.

Pitting corrosion is associated with the localised breakdown of the passive film (either due to imperfections or chemical breakdown) and as such, is commonly seen in stainless steels and aluminium alloys.

Chlorides are particularly aggressive to the passive layer so coastal environments are the most arduous. Alloying with molybdenum helps to stabilise the passive film on stainless steels so grade 316 is the more appropriate of the two commonly used stainless steels for use near the coast.

Crevice corrosion

This can be considered to be a severe form of pitting corrosion. It is associated with small volumes of stagnant water in tight gaps e.g., crevices and the gaps between joints. The crevices need to be large enough to allow the ingress of liquid but sufficiently narrow to maintain a stagnant zone. It usually occurs in openings a few thousandths of an inch wide.

This type of corrosion could occur in any tight gap between the nut/washer/hanger and between the bolt/staple legs and the rock or resin if water can penetrate.

As the corrosion is hidden it isn't easy to see, although telltale streaks of rust can give a clue. Again, grade 316 is the better than grade 304 in coastal environments for the same reasons as outlined above. Both crevice and pitting corrosion can lead to unforeseen failure of the equipment.

Exfoliation corrosion

Certain wrought aluminium alloys, particularly the stronger grades containing copper, can suffer from exfoliation corrosion. In this type of corrosion attack precedes along selective sub-surface paths parallel to the surface. In its early stages it appears that thin flakes are peeling off the surface but in its extreme form the metal seems to comprise of a series of layers loosely held together (like a wet book after it's been dried out and having roughly the same strength). Old aluminium hangers and many karabiners are subject to this form of corrosion – a good reason for not leaving old krabs on belays.

Stress Corrosion cracking

Although there is no evidence of this type of attack occurring in the UK, a number of bolts have failed by stress corrosion cracking (SCC) in Thailand and Cayman Brac so it's worth being aware of it if you're going sport climbing in the tropics.

SCC can occur in stainless steels in aqueous chloride solutions (e.g., seawater) so the bolts on sea cliffs appear to be most susceptible. Luckily for us, there is a temperature (~50°C) below which it doesn't occur (except in very acidic conditions) so it shouldn't be a problem in the UK until global warming really kicks in.

The corrosion is very localised and takes the form of cracks that can penetrate through the metal, reducing its strength to almost zero. These cracks can be very fine and difficult to detect on the surface and impossible to see how far they penetrate.

"My last month was spent climbing in Thailand on some very questionable bolts... About a week ago while I was waiting for a guided party to finish a second pitch on Thaiwand Wall, a leader broke a bolt by pulling on the quickdraw. This caused him to fall and break the next bolt. He was lowered off with a badly injured leg. Both bolts fractured in the shaft at the hanger."

*The Devil and the Deep Blue Sea
John Byrnes, Skip Harper and Mike Shelton*

Table 1: Stainless Steel Suitability

Stainless Steel Standards	Suitability for use	
	Inland	Coastal
AISI	304, 316	316
BS EN ISO 10088:2005	1.4307, 1.4432	1.4432
BS EN ISO 3506:1998	A2, A4	A4

Please note: these are general guidelines. Choice of surface treatment and anchor design greatly influence whether a specific bolt is suitable for use or not in a coastal environment.

Table 2: Alloy Compositions

Element	Stainless steel compositions wt% (Maxima unless stated otherwise)					
	AISI		BS EN ISO 3506		BS EN ISO 10088	
	304	316	A2	A4	1.4307	1.4432
Carbon	0.08	0.08	0.10	0.10	0.030	0.030
Silicon	1.00	1.00	1.00	1.00	1.00	1.00
Manganese	2.00	2.00	2.00	2.00	2.00	2.00
Sulphur	0.030	0.030	0.030	0.030	0.015	0.015
Phosphorus	0.045	0.045	0.050	0.045	0.045	0.045
Chromium	18.00-20.00	16.00-18.00	15.00-20.00	16.00-18.50	17.50-19.50	16.50-18.50
Nickel	8.00-10.50	10.00-14.00	8.00-19.00	10.00-15.00	8.00-10.00	10.50-13.00
Molybdenum	-	2.00-3.00	-	2.00-3.00	-	2.50-3.00
Copper	-	-	4.00	1.00	-	-
Nitrogen	-	-	-	-	0.11	0.11

FURTHER INFORMATION

Hilti

Manufacturer of mechanical and chemical anchor systems, drills and testing meters.

A good starting point if choosing to source industrial fixings and drills. Product specifications and installation instructions.

www.hilti.co.uk

American Safe Climbing Association

US based anchor replacement and education initiative.

Practical advice on removing old bolts, and placing new ones. Some destructive test data.

www.safeclimbing.org

UIAA

International Mountaineering and Climbing Federation.

Technical information on UIAA and EN standards for rock anchors.

"To bolt or not to be" the UIAA declaration on the ethics of redeveloping alpine regions.

www.uiaa.ch

Fixe

Manufacturer of bolts, hangers and lower off's.

Installation instructions.

www.fixeclimbing.com

Petzl

Manufacturer of bolts and hangers.

Installation instructions.

www.petzl.com

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Dan Middleton
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