HOW NOT 2 HIGHLINE

THE BOLTING BIBLE

VERSION 2.020

THE HOLE-Y GUIDE TO CLIMBING & HIGHLINING BOLTS

If you download the PDF, please check HowNOTtoHighline for the most updated version.

Researched, Organized and Written
by Ryan Jenks
(skylining@live.com)

This project has always been intended to be a free project because it is more important that people read this than to make $20. This has been a huge project and if you do read the whole book and gain useful knowledge from it, please consider ***DONATING*** *. We have about $10,000 into this book and our Bolt Buster tests, which are not sponsored, so we can stay independent. No, youtubing niche videos does not make money. We do this for the same reason our bolting angels go out and rebolt areas, to keep our crags and highlines safe and looking nice. Educating stoked bolters today is a scalable way to prevent future rebolting projects tomorrow.*

Acknowledgments

This book has had contributions or edits done by many experienced bolters. I learned everything I know from the people below. Thank you for helping with this comprehensive resource!

Major Contributions made by:

Bobby Hutton
David Kingston
Zac Timmons
Kim Weglin
Martin Roberts (Titan Climbing)
Travis Warner

Other Contributions made by:

Greg Fishell
Jediah Doohan
Philipp Gesing
Jason Fautz
Ryan Morse Brady
Mike Law
Andrew Davidson
Alex Rybchuk
Chris Wallace
AAC
Ben Iseman
Marc Thompson
Jerry Miszewski
Scott Rogers
Clay Lippincott
Greg Barnes
Mark Hanna
Jim Titt
ASCA
Access Fund

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THE OLD TESTAMENT

All about bolts, and how to put them in rocks...

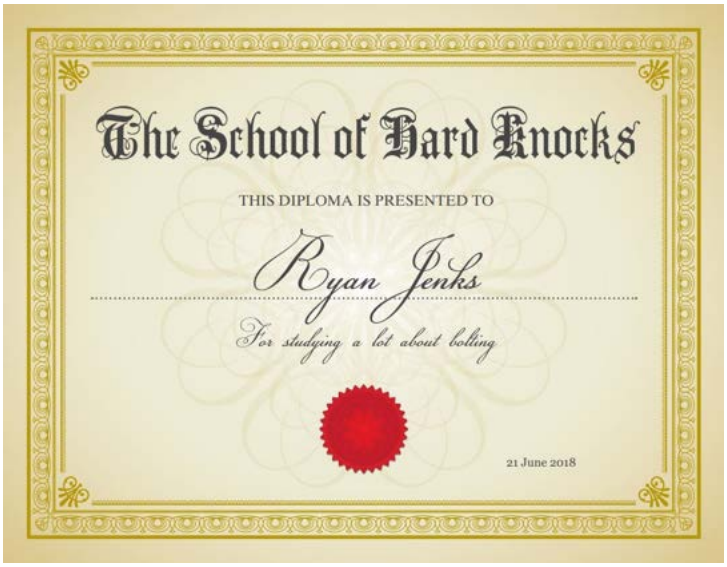
THE NEW TESTAMENT

How to remove & replace bolts + Bolt Buster break tests ...

Disclaimers!

<u>This book is for entertainment purposes only</u> and aims to overwhelm you with the daunting task and responsibility that it is to bolt... in hopes that you decide not to bolt. If you do bolt, please put in products that will pass the test of time. Please don't "learn" by installing permanent anchors that you, and thousands of other strangers, will depend their lives on for many years, but rather practice in a non-critical setting (like your backyard) until you know that what you will install will be safe for everyone.

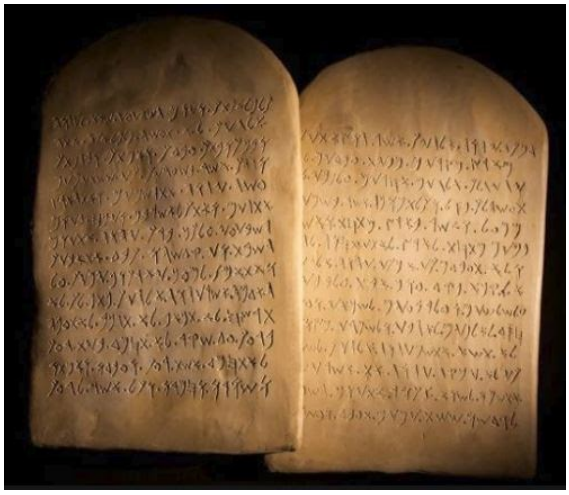
I am fully certified in absolutely nothing. I was hardly taught anything in person. I have installed bolts less than perfect before. This is a collection of all the information I could collect from reliable resources online, the people I respect and the testing we have done ourselves.



Though I have tried to include all the best practices accepted to date, the information is not confirmed, tested thoroughly, or could just be outdated. Ideally this Bolting Bible could be the only source you need to visit to get all the available information online about the topic, but keep in mind that it is just as reliable as anything you find on google (aka not reliable).

The 10 Bolting Commandments

1. **Thou shalt not drill where thou art not allowed**
2. **Thou shalt never place zinc-plated bolts**
3. **Thou shalt practice bolting at home and not in nature**
4. **Thou shalt really, really clean thy hole after drilling**
5. **Thou shalt never spray thy bolts**
6. **Thou shalt check thy glue-ins after thy glue cures**



7. **Thou shalt only drill thy holes perpendicular to the rock face**
8. **Thou shalt not bring thy power drill to thy National Parks or Wilderness areas**
9. **Thou shalt never use wedge bolts in soft or fractured rock**
10. **Thou shalt read the entire bolting bible so thy knows what thou is doing**

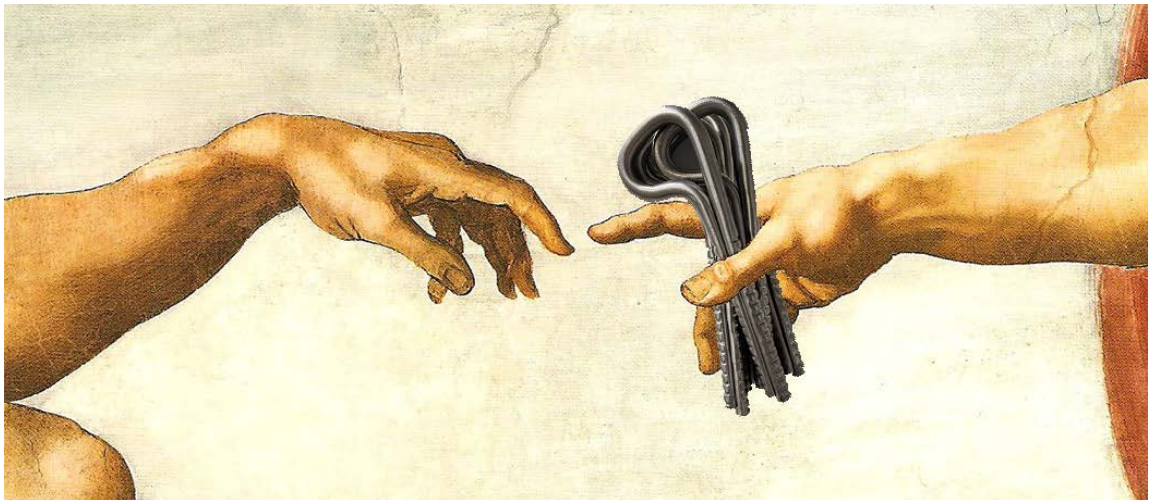
The Armor of Thy Bolter

Be strong in bolting and it's mighty power. Bring the full armor of thy bolter, so that you can stand strong against the adversary of epics. For our struggle shall not be against simple things of this world like logistics but against the all important details of technique, changing weather and our beers getting warm. Carry with thee, thy drill of truth, thy drill bit of righteousness, thy bolt of faith, thy hanger of peace, and thy eye protection of salvation.

Why the Bible Theme?

It shocked me in my bolting research how dogmatic people were about what they believed and how another would have contradictory evidence about it. Online, generally people can be dicks or act religious about shit they don't know anything about. Let's be nice to each other. It takes a lot of work and money to install bolts. Let's encourage each other to do the best bolting possible but not be trolls while doing it.

Just like the Bible has many authors and contributors, this too is a collaborative effort with many bolters so it can be a resource that is considered "best practices". We worked with many bolters and have feedback all the time. Unlike the bible, if you find something that needs correcting, we will update it!



Why the innuendos?

Because writing and reading a book about bolts is as dry as the dust you get from drilling rock. Our target audience isn't just the 20 people around the world that nerd out on bolt details or even those who install bolts, but everyone who depends their lives to these metal things they see in the rocks and know nothing about. Plus we can't help using a good pun!

How NOT to Highline

It started with a few highline tutorials in 2016 and has become a combination of myth busters, jackass and SNL for highlining and climbing. We love when useful information is packaged in a fun way. In my effort to learn bolting, the information seems to be scattered all over the internet and I love organizing things, so here is the Bolting Bible. We break shit and do human testing on our channel so be sure to subscribe because we post bolt related videos all the time. We post our episodes on Instagram and Facebook and Youtube.

Watch all of our bolt videos on this *PLAYLIST*

The Old Testament

All about bolts, and how to put them in rocks...

The Book of

BOLTING ETHICS

"Thou shall not penetrate virgin rock without feeling guilty."

Should we bolt just anything we want? Are installing just whatever bolts we have super good enough? Bolting for climbing and highlining can create access issues in areas that we share with other people. So let's dive into if and how we should be placing bolts to make our climbing routes and highline anchors bomber for everyone.

Chapter 1 - Ethics EPISODE

In the beginning, bolt ethics have been in heaven and on earth. No, seriously though, ethics just take into account how it affects everyone, not just rope monkeys. Laws regarding bolting are not always keeping up, but that doesn't mean it's ok to do whatever we want. A bolt is a permanent human object out in beautiful nature. Think twice, or 3x before placing a bolt. Here are some examples of things that may be legal(ish) but highly frowned upon:

- National Parks in USA
- Top of climbing routes!
- All natural climbing crags
- Wilderness area
- Single use highlines that won't be rigged often or climbs that won't be repeated
- High traffic pedestrian areas (ie lookouts or next to popular trails)

Chapter 2 - Rules

There are some clear cut rules for certain areas. Learn them! For example, power drills cannot be used in National Parks, everything must be hand drilled. Different countries have different rules. Know an area well before putting in a metal version of graffiti. Many bolters get the same dopamine response as graffiti artists after seeing something in public that they created. The feeling will be there, that is fine, just make sure you are not installing bolts just for that feeling and that it is helpful and legal and ethical.

Chapter 3 - The Area

If you choose to bolt and it is ethically ok to do so, then thank you for taking your time and money to do so. However, please choose the spot carefully!!!

- Does this location deserve a permanent anchor? Will this line or climb be repeated and is it a benefit to the community? If bolts are required, can you use removables instead (more applicable to highlining)?
- Is there a good spot for bolts to be placed? What is the quality of rock like?
- Can you strategically place bolts to minimize no fall zones?
- Can you strategically place bolts so they can't be seen by those not using them?
- Can there be a hybrid of natural anchor/bolts? Maybe only one side of a highline needs bolts and the other doesn't. Maybe part of the climbing route can be climbed with trad gear.
- If the highline anchor is directly above a climbing route, can the bolts be placed elsewhere to avoid conflict and confusion.
- Are there enough other routes and lines already at this location? Will this area benefit from another line or are you just doing it for your ego?

Chapter 4 - YOU

YOU are the #1 risk of any bolt failing. It is a huge responsibility to install a bolt that other people will literally depend their lives on. It is practically impossible to inspect a bolt after it is installed so we just "hope" it was installed correctly when we show up to climb or rig a highline. Realize what kind of role you are playing and respect the responsibility, educate yourself and please please practice. This VIDEO shows bolts being pulled out with body weight after someone died using them in the area!

Practice at home in concrete. If you practice on a rock, be sure it is in an area no one will ever see. Don't make a major crag or highlining area your testing grounds. If your first thought was, "I don't want an ugly hole at my house," then you are well on your way to really understanding the issue some people have about bolts being in our beautiful shared public lands. Spend the money on a tube of glue to understand how it mixes and to make sure you have the right caulk gun. Install a glue in at home to understand how that shit gets everywhere. Pull it out before it cures and clean off the bolt with goof-off if you don't want a bolt in your yard for the next 50 years. Spend the time hand drilling one bolt in your backyard to understand what is involved and how to make sure the hole stays straight. Install a mechanical bolt with a torque wrench at home and with a normal wrench so you know how tight to make it in the field if hiking in a torque wrench is not practical. Practice. Practice. Practice.

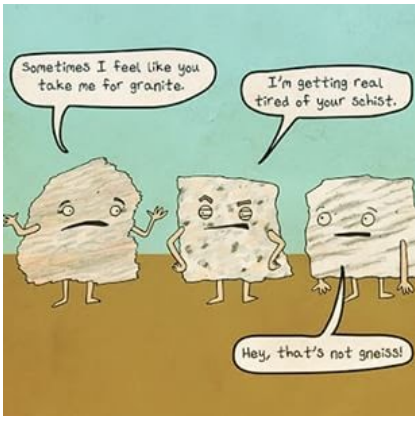
Chapter 5 - Rigging Naturally

Hey highliners! If possible, please rig naturally. This means rigging a highline without any use of bolts and "naturally" is a "leave-no-trace" method of highlining. Generally trad gear like cams, tri-cams, nuts, etc is used or trees and boulders are wrapped with ropes and spansets. I find that rigging a line "naturally" brings more satisfaction as it requires more creativity. Though it can be screwed up easier than just building an anchor on bolts, it generally should be built with enough redundancy that it is just as safe if done right. We teach all natural highline rigging at Highline University International (www.howNOTtoHighline.com)

The Book of

ROCK

"The harder it is, the better it is for your hole."



Bolts are only as strong as the rock you put them in. Some rock is soft and some rock has more layers than onions. The rock, not the bolt is holding your life, the bolt is just hanging onto the rock. So let's learn the basics to have a "rock solid" foundation!

Chapter 1 - General Rock Biology

It is important to understand the KIND of rock you are working with so you know what bolt will be the safest to use. To keep it simple, we will divide rocks into 3 categories. Hard rock, soft rock and layered rock.

Rocks are made up of minerals. Minerals are what make, or break, the rocks' strength. What you need to know about minerals are their hardness and their resistance to weathering. Quartz, a common sand grain in sandstone, and a common crystal in granite, is incredibly hard and resistant to weathering. Feldspar, like quartz, is incredibly hard, but weathers easily and turns into clay. Clay minerals are soft, and also weather easily into other soft clay minerals.

Chapter 2 - Hard Rock (not the cafe)

Hard Rock would be any rock that is, wait for it, incredibly hard, typically unweathered granite and quartzite sandstone.

Granite is the result of magma having cooled very slowly underground (plutonic rock) allowing the quartz and feldspar crystals (among other minerals not nearly as important) to grow big and tightly against each other, leaving no

spaces. Yosemite granite is smooth from glaciers polishing them and Joshua Tree granite is rough because it sees very little water to erode it. But both formed and cooled underground and therefore are very strong. And both haven't seen the excessive chemical weathering (think acid rain and/or seawater) to have turned the hard feldspar to soft clay.

Quartzite Sandstone is quartz-rich sand, cemented together with quartz cement. So the whole rock is nearly 100% quartz. Quartzites are the typical ridge-formers of sedimentary basins, like the Sandstones at New River Gorge, WV.

Bolts in hard rocks can be installed closer to an edge (within a foot or two). Strength of hard rocks is above 14,500 psi and goes up to 30k and even 50k psi for some.

- MECHANICAL BOLTS - Granite or other hard rock is perfect for all kinds of mechanical bolts, just be sure they are stainless steel.
- GLUE IN BOLTS - These work just fine in hard rock but there are 2 schools of thought. Glue ins can be frowned upon in granite as it can be considered overkill and replacing them can possibly be more difficult than mechanical bolts. The reason some people choose to use glue ins with fixed eyes is because there are no threads to get screwed up, no one can steal hangers, and the fixed eye allows highliners to thread static rope through rather than needing quick links. Glue ins typically have less visual impact than a standard climbing hanger.

Chapter 3 - Soft Rock

Soft Rock can be sedimentary or magma based. These are typically non-quartzite sandstones (where the sand-grains, or the cement, or both, are not quartz-rich, and thus prone to weathering and weakening), limestone (calcium carbonate), volcanic rocks, and excessively weathered granites. Just like tall tales, porous rocks with a lot of holes don't usually hold up!

Sandstone is literally compressed sand, glued together with chemically precipitated cement. The cement and sand grains are made of various

minerals, each with different hardness and resistance to weathering. When either the sand or the cement is not quartz, the sandstone tends to be much softer, because the grains/cement may have weathered to clay (or weathered out altogether, leaving pores). To "scientifically" test a rock's hardness out in the field, hit it with a hammer! If the rock sparks, it's hard rock. If the rock breaks, it's soft! You are looking for a solid sound and not a hollow thud.

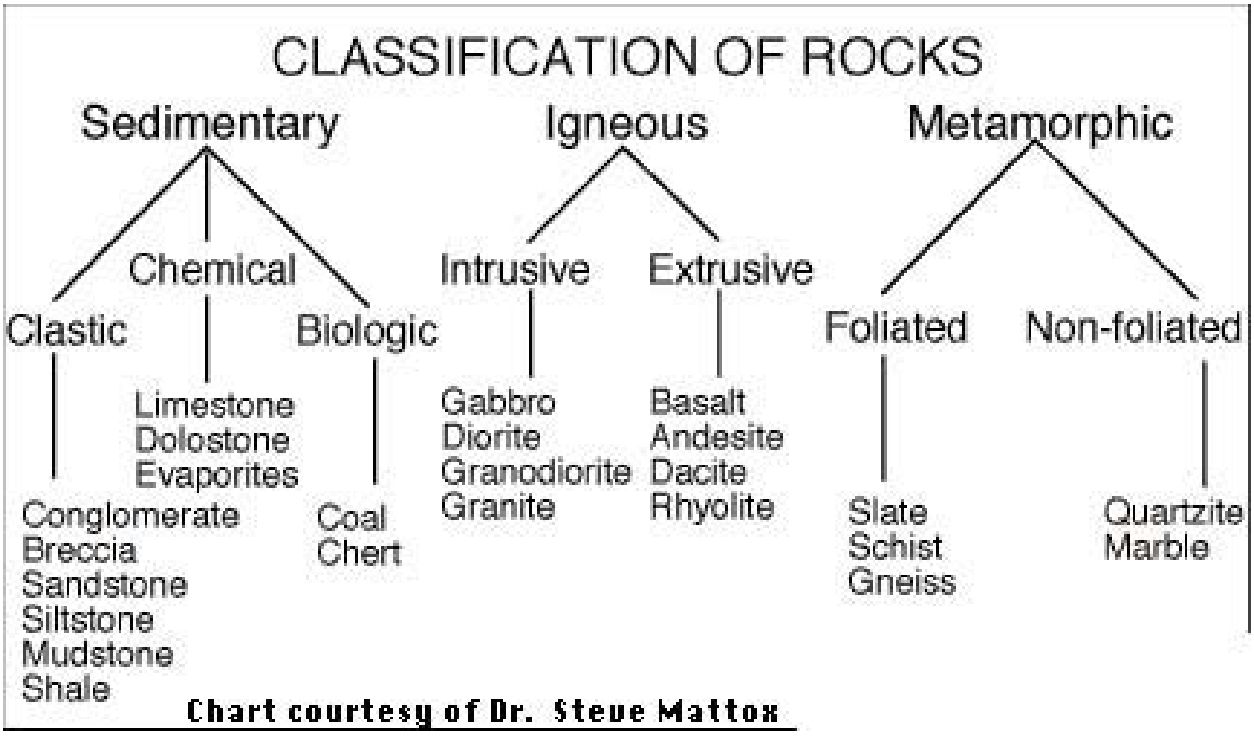
Limestone is calcium carbonate (mineral name: calcite), often from dead marine life, squeezed together to make rock. Calcite is moderately strong, but it weathers into CO2 and water (i.e. nothing) when it reacts with acid rain. Think sinkholes and caves. So its structure tends has a lot of microscopic holes in it which makes it weaker.

Volcanic rock is from lava, so it cooled rapidly on the surface, not allowing the crystals to grow big and interlock. Also, lava tends to have lots of gasses dissolved in it, so as it cools it tends to be porous from the gas bubbles getting trapped. Small crystals and pores make volcanic rocks weaker than a slow cooling (unweathered) granite. Rhyolites and basalts, and volcanic ash "Tuffs" are typical volcanic rock names. We tested bolts in terrible volcanic rock in this **EPISODE**

Bolts installed in soft rock need to be placed further back from edges in the most solid part you can find. It's also quite unsafe to put pressure on bolts installed in soft rock when they get wet, like after a rainstorm. Cyclic loading mechanical bolts in sandstone compromises placement integrity. In Moab, Utah, it's highly recommended to let the rock dry out thoroughly before highlining on those bolts. In Zion National Park, you are not supposed to climb on that soft sandstone for 2 days or it will compromise the rock and gear placements. Soft rock strength (dry) can be as low as 500 PSI and up to 7,000 PSI.

- MECHANICAL BOLTS - The softer the rock, the less force these will hold. Wedge bolts are not recommended because the engagement contact point is quite small which can compromise the placement in soft rock. Some sleeve bolts are ok because there is more contact area (like 5 piece Power bolts - STAINLESS).

- GLUE IN BOLTS - This is where glue shines. Glue gets into all the rock pores therefore can pull on the entire rock surrounding the bolt stud rather than all the pressure being placed on a few millimeters of the sides of the hole with mechanical bolts.



NOTE: Rocks fall (get it?) all over the hardness chart - and this is because of their varying mineralogy. It's good to know the area you plan on drilling so you can install the safest bolt possible. Some sandstones can be very very hard like New River Gorge, WV (quartzite) and some granites can crumble in your hand like the kind at Cabo San Lucas baja tip (feldspar, aka "Arkose", now weathered to clay-rich granite).

Chapter 4 - Layered Rock

Layered Rock is rock that has well-developed horizontal partings. In sedimentary rocks, these partings are bedding planes, where sedimentation stopped, and then restarted again. Sandstones, shales, and limestones can all be layered. In igneous rocks, especially granite, horizontal partings can occur that are called "exfoliation fractures". These

occur when igneous rocks are exposed at the surface and the pressure (of having been buried for millions of years) is released. The rock expands, and cracks like an onion. Metamorphic rocks (slates in particular) tend to be layered as well, due to the shearing forces typical with metamorphic processes. Shearing causes the rock to foliate (or makes all the minerals in a rock align with one another in a preferred plane), causing onion like flaking, or part along the shearing plane.

Layered rocks can be tricky to bolt. The rock may be hard but comes with crack, and anybody on enough crack isn't going to be reliable! An example of this is the Dinorwic Slate Quarry in Llanberis, Wales. (David Thexton) Another example of this is the limestone in Ontario as the limestone has been compromised by vegetation from the roots cracking it.

- MECHANICAL BOLTS - can promote more cracking and are NOT recommended
- GLUE IN BOLTS - Glue can grab the whole sandwich of rock layers giving better holding power.

Chapter 5 - Rock Inspection

SOLID ROCK - Regardless of what rock you are drilling into, make sure it is a solid piece! Hit it with a rock density detector… aka… a hammer. You can hear the difference of solid rock with a high pitched ping rather than a dull thud on hollow rock. You can also put your hand close to the spot and if you can feel the vibrations, the rock is NOT solid.

BIG ROCK - Be sure you are not just on some large flake or suitcase sized rock. Check to see if the rock is thoroughly attached to all the other rock around it and not just a boulder sitting in the dirt. Sometimes even car-sized rocks are just barely attached to a rock face. Your bolt might hold but the rock might not! Think about the big picture of how that rock is attached to the earth.

This chapter is covered in this EPISODE

The Book of

HOLES

"After getting thy hole hammered, make sure thou cleanest it really well."

Holes matter a "whole" lot! You have to know where to put them, what pattern to put them in, how to drill them and what diameter they need to be, even sometimes accurate to within 0.1mm. And did you know that if they aren't super sterile clean, at least for glue in bolts, they could fail at a dangerously low force? Keep in mind drilling a hole is a permanent deformation to the rock, so be intentional before you swiss cheese our public land. See here all the things you need to get your holes drilled out.

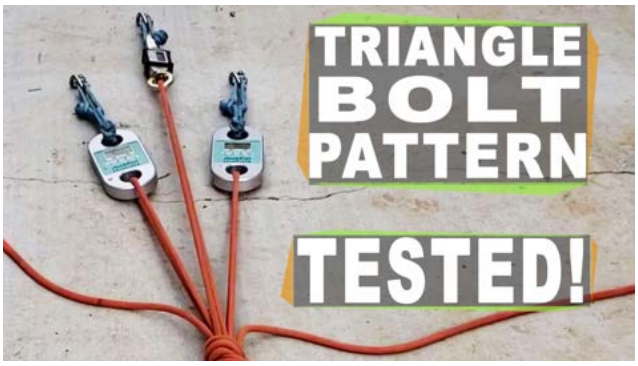
Chapter 1 - HIGHLINE bolt placement VIDEO

Things to consider before installing highline anchors

1. **Where do you want your master point to be?** It will be in the center of your bolting pattern so choose carefully. And remember you don't want more than a 45 degree angle on your anchor legs so it doesn't put exponential force on the bolts, rather than sharing the load evenly.
2. Is the anchor going to serve more than 1 highline? How can the bolts be placed to best be pulled in multiple angles?
3. Will the hangers sit flat against the rock?
4. Will there be a weird hump between the bolts and the masterpoint causing unwanted friction?
5. How far back from the edge will the bolts be?
    a. In hard rock it can be a foot or two away from

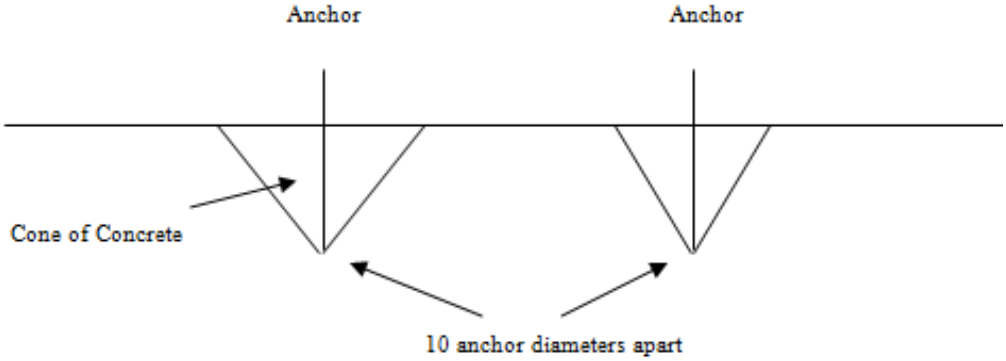
edge but if it is too close then it can put the master point too far beyond the edge making rigging a bitch.

b. In soft rock it is important to stay away from the edge even 6 to 10 feet back in some cases but then the master point will need extending



6. What Pattern will you use?
    a. Straight line - Careful, this is how they harvest quarry stone. This can score rock and make it susceptible to fracturing. Know your rock. STRAIGHT LINE PATTERNS DON'T EQUALIZE on top of cliffs but being pulled straight out of cliffs may equalize better.
    b. **Equilateral Triangles** equalize best if on top of a cliff. The bolt most direct in line (the center bolt) and the closest bolt sees the most force. Those two principles cancel each other out for the most part if you do an equilateral triangle, with the center bolt being furthest back.
        i. What is the perfect bolt pattern?
        ii. Equalization is NOT a myth
        iii. Testing Triangle Bolt Patterns
        iv. Learn more about directional relativity here.
7. How close, or far, should the bolts be apart from each other?
    a. The force is spread at a 45 degree angle through the rock. You can see an example in this photo of a piece of sandstone that broke while pulling a short mechanical bolt straight out in a bolt buster test. If your bolts are too close together, the same sections of rock will be seeing forces from two different bolts. It's also important to not be too close to areas of the rock that you hear are bad when you checked with your hammer. The **longer** your bolt, the bigger your cone will be, so the further your spacing will need to be. The expansion anchor industry has established a minimum of 10 anchor **diameters** apart from each other (½" x 10 = 5" or 12mm x 10 = 120mm apart minimum) but I'm

not sure diameter really has much to do with it. For most climbing situations, a hand width apart is fine but in softer or fractured rock it is better to spread them out twice as far.

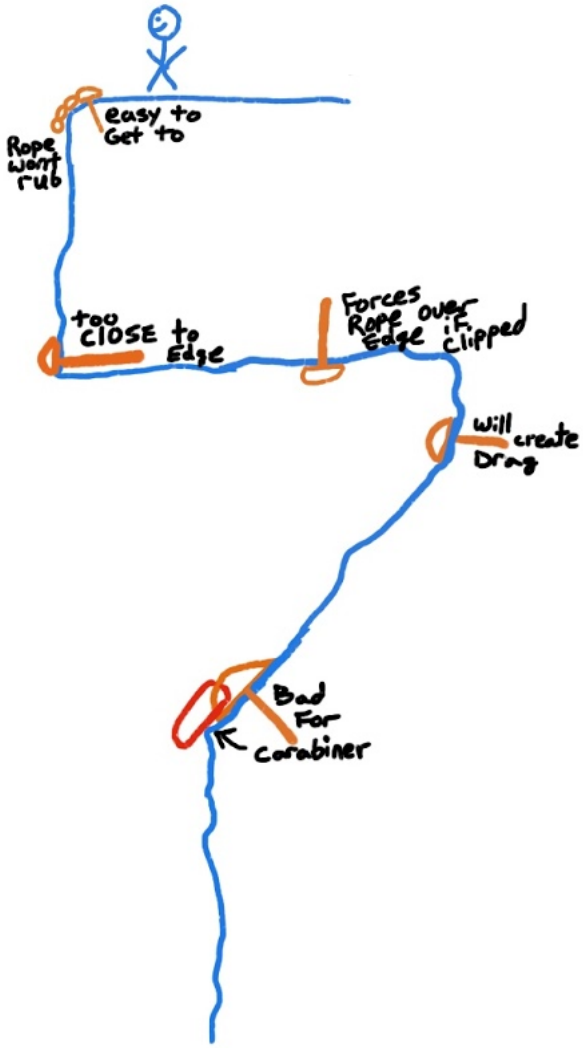


8. How many bolts will you use?
    a. HIGHLINING - 2 bolts are redundant and 3 is common for highline anchors. 4 bolts are overkill and it is difficult to equalize them so only 2 or three bolts ever see the force anyways. Just make sure you have quality bolts in quality rock. See our equalization is a myth series. Links above
    b. CLIMBING - Things to consider: how high is the route, where are the cruxes, what is the complexity of installation. See The Book of Climbing Anchors section below for all the options there.
9. What are the regional trends and is it correct? Don't do anything drastically different than others have done in the area without fully understanding why they did it.

Chapter 2 - CLIMBING BOLT PLACEMENTS

Things to consider before installing climbing bolts, or a list of things you can complain about on the next route you climb.

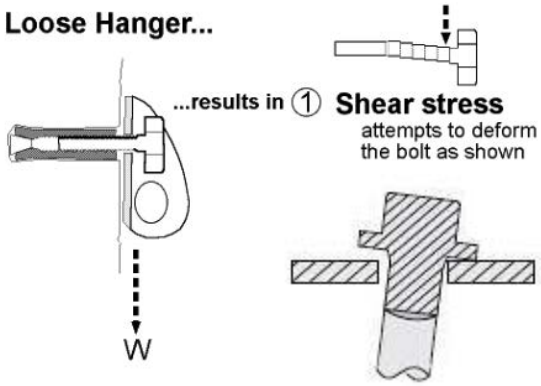
1. To avoid rock failure, place bolts an appropriate distance from rock edges, further in softer rocks.
2. Avoid placements that weaken your carabiner by loading it over edges or rock imperfections.
3. Plan placements to avoid rope drag. Keep bolts on a sport route in line to avoid the friction of the rope redirecting back and forth across the route.
4. Avoid placing anchor bolts too far from the cliff edge, forcing the rope to rub.
5. When bolting sport routes, find good clipping stances, then make sure to place the bolt so most climbers will be able to reach it. If you are 6'6" don't place it as high as you can so a shorter climber will be able to comfortably use the same stance to clip the bolt.
6. Consider when a quickdraw is hung on the bolt that is won't be in the way of a key hand or foot hold as you climb past.
7. Place top anchors so they protect as much of the route as possible. If the route wanders, place the anchor in the middle point of traverse to prevent big swings on top rope.
8. Hitting the ground or ledges is bad. Place bolts to avoid this.
9. When putting in anchors for a climb that will only/mostly be top roped, consider the safety of those walking to the cliff edge to set up the climb.



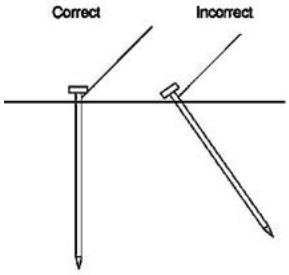
Chapter 3 - Drilling Basics EPISODE

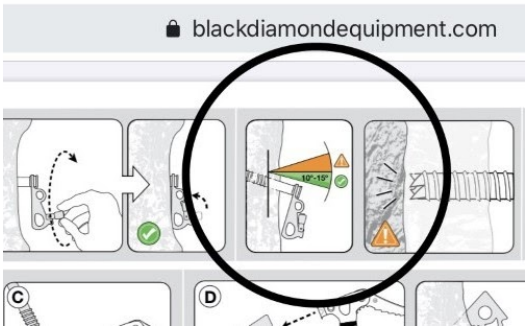
Here are some pointers for drilling holes regardless if you are hand drilling or power drilling.

1. Drill the hole long enough. In almost every situation, there is no such thing as too deep other than you are wasting battery life, drill bit life or glue. IT IS VERY BAD IF THE HOLE IS TOO SHALLOW. Just like relationships, if it is too shallow it isn't going to last. A bolt sticking up out of the rock is not safe to use and difficult to remove. If it is even 95% deep enough it will look like it is in the rock but the hanger will be spinning and that always raises a red flag on the integrity of the bolt to someone who wants to use it.



   a. TIP: Put duct tape on your drill bit or your wire brush to verify that you are deep enough.
2. Drill it straight.
   a. Mechanical bolts will have a hanger and it is important that the hanger sits flat against the rock.
   b. Glue in bolts have conflicting information online. FixeHardware says in this video to tilt them backwards for leverage. Bolt-Products website (scroll halfway down) did a test showing stakes in the ground do better if installed straight in. I believe glue in bolts act much like ice screws where the threads are supposed to do the work, not the leverage. Ice screws are recommended to be tilted 10 to 15 degrees towards the direction of pull so it doesn't leverage the top of the ice but allows all the threads to be pulled on. So just drill glue ins straight in for soft rock and let the entire shaft and glue do the holding rather than the angle.





3. Test the spot
    a. Set the hanger (if using hangers) where you think you will drill the hole to make sure it sits flat and nice. If you really like the spot and only a few crystals are stopping you, you can chip them away, but just be sure the end product… the hanger… will sit nicely.

    b. After drilling the hole an ⅛", stop and check everything again. Do you like the spot? Does your hanger sit nicely? Did the rock feel/sound solid? If you goof, ⅛" isn't a deal breaker, but if you drill all the way and then realize there was a mistake, then it is just slop.
4. Bring Backups
    a. It really sucks if you don't have a backup drill/batteries or backup bit or backup glue tip or even backup hardware in case you miss counted or dropped one and you can't finish bolting. The impact that bolts have on an area has been debated, but everyone agrees a half drilled or half installed bolt is bullshit.
5. Drill Bits
    a. A 4-point bit drills faster and saves energy or batteries rather than 2-point bit. They also make a rounder hole which is important for some bolts such as those overpriced petzl removable bolts.

    b. Fresh bits are important because the tip/shoulders get worn down on old bits and you get an undersized hole. If the hole is too small, then you have to smash your mechanical bolt in harder which can damage it or the glue in will not have as much glue surrounding the rod.
    c. Battery powered hammer drills and Petzl Rocpec hand drills require SDS-Plus drill bits, "special direct system". These kind have the groves at the top so the drill can hammer and rotate the bit. Not all SDS bits are created equal. SDS-Plus is 10mm shank and SDS-Max is 18mm. So make sure you know what you are buying.
    d. Size matters - the usable length and overall length are generally different by 2" because of the shank, or the part that goes into the drill. Remember that a 6" drill bit only has 4" that is usable.

It helps to understand all 5 parts:

i. Shank: has two sets of grooves so the bit doesn't fall out and helps during hammering.
ii. Land - raised portion of the spiral (similar to the crest or peak of a wave).
iii. Flute - the spiral groove which facilitates the removal of the concrete dust as the hole is being drilled.
iv. Head and Tip - these work together to break up the concrete. The carbide is brazed onto the head to harden the tip of the SDS bit to assist in the breaking of the concrete.

Credit: https://www.confast.com/

Chapter 4 - Hand drilling

There are some places that do not allow power tools, such as National Parks in the USA. However, if it is legal and ethical to install bolts, you can do it the ol' fashion way… by hand!

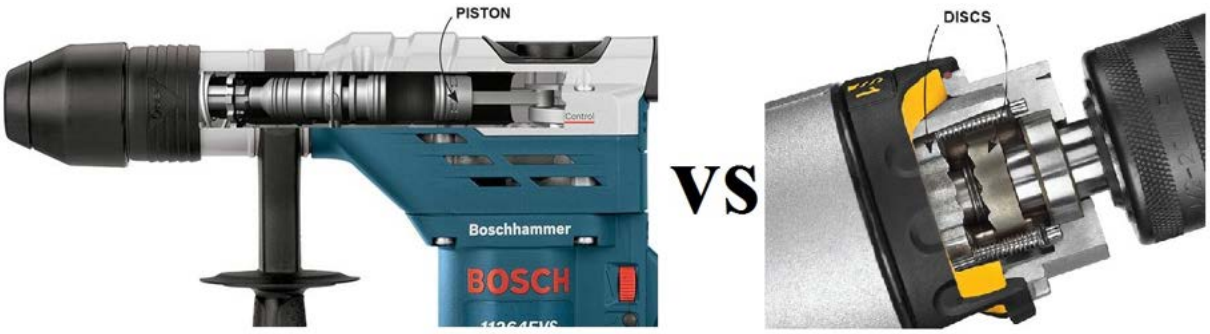
1. You need a handle. The poor man's method is to duct tape the shank with about 50 wraps but the efficient way is to use a Petzl Rocpec , designed for SDS drill bits or the high quality D/5 Hurricane Drill which is designed for both SDS and HSS bits.
2. You need a hammer… obviously. You can use any 12oz construction hammer but the Yosemite Hammer has an attachment cord and an eye to attach a carabiner for clipping and the occasional yanking.
3. Use gloves! The thicker the better for when you occasionally miss the head of the drill.

4. Use eye protection! You can literally feel things hitting you in the face when hammering a rock. You don't want rock shards in your eyes. You can use sun glasses, you will look cooler when explaining you are trying to create a hole in granite the same way they did 200 years ago.
5. How long does it take?
    a. A 4 ¾" x ½" bolt hole takes approximately 1000 hits in hard Yosemite granite. Counting is a great way to keep the stoke high. Try to hit it at least 50x before resting your arm. Find and keep a rhythm to the hitting rather than pretending you are the road-runner on crack and getting tired 20 seconds later.
    b. It takes about 45 minutes to an hour for A single 4 ¾" x ½" bolt hole in hard Yosemite granite. Softer rock can be much much quicker but you may have to drill for a longer bolt.
6. Keep it straight - As you get tired, you may have a tendency to not keep the drill straight. If the drill isn't perfectly straight, it will be dragging against the sides of the hole and the friction that creates can really slow down momentum. It's also very important to keep a drill straight so the hole stays true to size.

7. Don't give it a courtesy tap, hit the drill with some umpf! You're not trying to make noise, you are trying to burrow a hole in rock!
8. Keep the hole clean periodically. Maybe after 100 to 200 hits. If you don't, you are just pounding dust… literally!
9. Use the most important resource on the planet… friends! If the anchor is safe to "hang out" at and easy access for everyone, take turns. Hitting 100x and switching can speed things up and not feel like such a burden.
10. Keep it attached to you. Wouldn't it suck if your hammer or drill rolled off the cliff or fell out of your hands?
11. Use fresh bits. This is especially important for hand drilling. That extra $10 won't seem like much if you are only half done after 1000 hits because you are using a worn out bit.
12. Don't slack off! Install a ½" or 12mm bolt if you plan to highline on it, but ⅜" bolts are fine for most climbing applications.

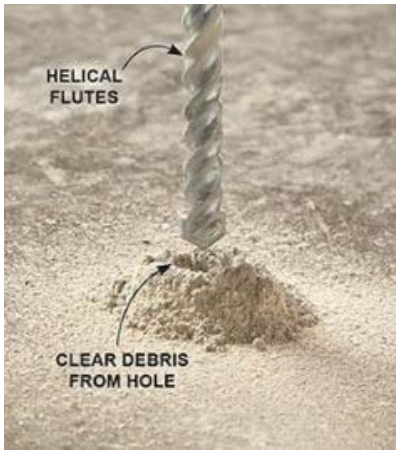
Chapter 5 - Power drilling

1. Hammer drill vs rotary hammer drill - rock isn't threatened by a normal drill spinning, you need a hammer drill. However, a normal "hammer drill" only has 2 cam/discs/gears spinning and tapping each other and is designed for "light masonry". Unless you are drilling into some really poor quality rock, you will want a rotary hammer drill. Those have pistons which chisel the rock while spinning. Hammer drills have a normal chuck in which a smooth shank fits in and Rotary Hammer drills require SDS bits. You can buy the best at Bosch or save some money and buy the one from Makita that works just as well (i'm very happy with it) or Milwaukee has a great one too for the same price (Bobby Hutton really likes this drill).



Rotary Hammer Drill **Hammer Drill**

2. Keep it straight - it's common for people to think a drill is straight and it be completely at an angle. With all the vibration and noise, you really have to be intentional to keep that drill perpendicular to the rock. There's no fixing a hole drilled at an angle after you see the hanger doesn't sit flush with the rock!
3. Check your work after the first 2 seconds of drilling. Make sure that it is where you want it. Don't check once and drill twice. Let's avoid swiss cheese rocks by being mindful about checking our work.
4. Don't push hard. Let the drill do the work.
5. Don't be afraid to pull out. To help clear the debris, just pull the bit out periodically while it's spinning. Not the entire time like you are trying to have sex with the rock, but you don't want to just leave it in the hole for 3 straight minutes either. :)



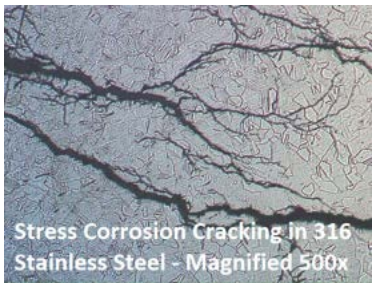
6. Know your batteries and bring enough. Don't run out of juice and not be able to finish.
7. Know your target length. You don't always want to drill the full length of the bit so know how much of the shaft has to be buried and keep an eye at that spot. Many drills have a measuring stick built into the handle called a "depth stop". Or you could go fancy and put duct tape on the drill bit to identify the right depth. Just don't drill too shallow, it can create major problems. Remember notched glue ins need to have a deeper hole than glue ins with no notch.

This **EPISODE** covers this chapter. Watch all of our bolt videos on this **PLAYLIST**

The Book of

METAL

"Make sure it is hard and that it lasts a long time!"

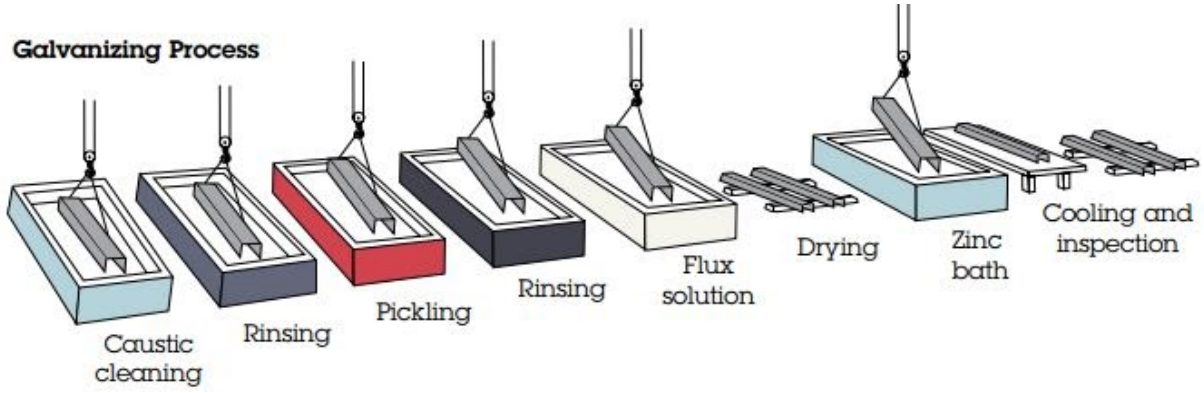


Just like mom always said, "it's what's on the inside that counts!" What your bolt is made out of really matters if you want it to last a long time. Most of the bolts you see on the shelf at the local hardware store, are not going to make it more than just a couple seasons. And you can't just buy whatever you want on any bolt-specific online retailer, even if they just market directly to climbers. Sometimes they sell interior products without them clearly labeled as such (ahem… Fixe).

Chapter 1 - Zinc

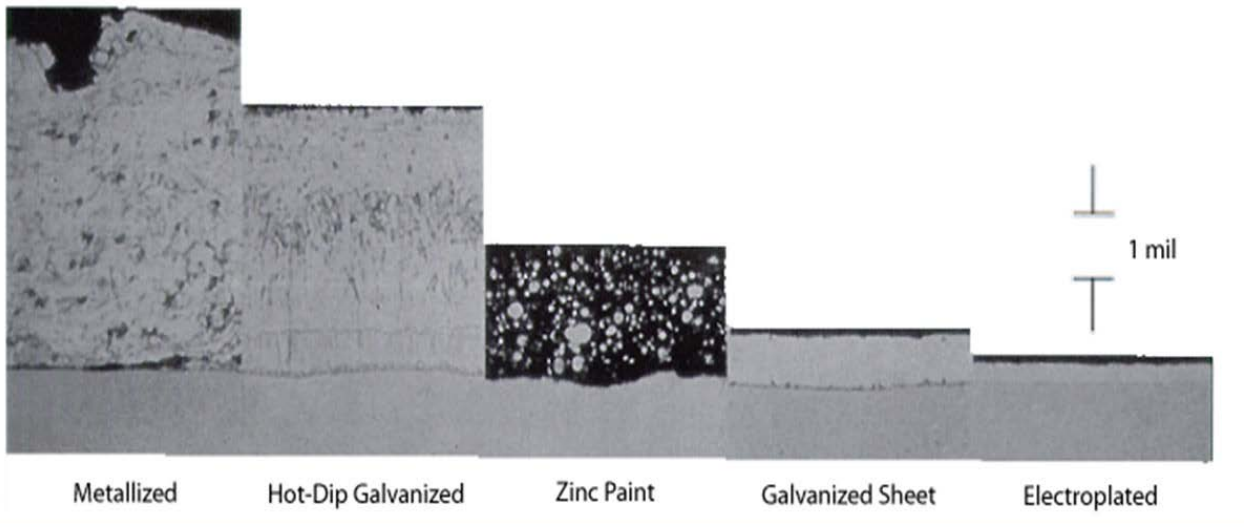
Iron ore is mixed with carbon and processed into steel which is the most common metal used on earth. Fun fact - there are over 3,500 different grades of steel! If steel is left exposed to air and water, it will rust. Painting steel, like on cars and bridges, slows the corrosion process down, but paint is not practical in many applications as it doesn't last very long and will wear off when there is constant metal to metal contact like in climbing.

So the next level of protection is to use chemicals and electricity to apply a very thin metal coating to protect it. Zinc can corrode up to 100x slower than other metals, so steel is often "zinc-plated". Fun fact - zinc isn't a hard metal, in fact it is less than half as hard as steel (159DPM hardness vs 70DPM hardness). The zinc is a "sacrificial coating", so when it is plated on steel, it will always tarnish and corrode first. However it is very thin, and naturally doesn't give long term protection in any environment with moisture. Plated steel is generally intended for interior uses.



To make steel last longer, more zinc can be added. However that takes a completely different process called galvanization. Hot-dipped galvanized coatings is a 7 step process creating a metallurgical bond and can achieve a bond of 3,600 psi (harder than the base steel). This creates the rough surface you see on galvanized nails, but since the threads on galvanized screws can't be too rough, it is spun in a centrifuge to clear the threads of excess zinc, though it still requires an oversized galvanized nut.

Think of cooking a piece of chicken in a pan with a little oil in the bottom (zinc plating) vs deep frying that turkey (galvanizing). They both have oil on it, but one has a much thicker coating. Zinc plated products are not intended to be an outdoor building material, but galvanized is, however it doesn't last forever and is not an ideal outdoor anchor. Plated steel bolts can last as little as 3 months in areas like Thailand, Brazil or Hawaii before they can be broken off by hand.



Chapter 2 - Stainless

The word “stainless” is thrown around like it is a type of steel, when in fact there are 5 types or categories with a total of 150 grades. Chromium and nickel are the 2 major ingredients to make steel more resistant to corrosion (not corrosion proof). They don’t plate steel with these metals, they melt them together creating an alloy. The two different grades you will see in climbing bolts are 304 and 316 stainless.

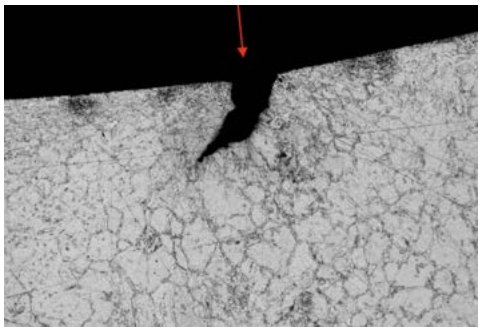
304 Stainless Steel is also referred to as 18/8 (18% chromium, 8% nickel). Most stainless climbing bolts and hangers are made out of 304 grade and are significantly more resistant than any plated steel but fail quickly when near the ocean.

316 stainless or “marine-grade” is 18% Chromium & 10% Nickel & 2% Molybdenum, and less than 1% of carbon, phosphorus, sulfur, nitrogen. The Molybdenum is added to help resist corrosion to chlorides (salts) like in coastal areas. 316SS is the most corrosion resistant mechanical bolt that you can buy since titanium isn’t available as a mechanical bolt (only as glue ins). However, in the harsh conditions of Thailand, Brazil and Hawaii, 316 stainless climbing bolts can completely fail within 3 years and so something even more corrosion resistant is required.

Duplex stainless or PLX stainless or HCR (high corrosion resistant) or 904SS or steel grade 1.4362/1.4462, whatever the hell you want to call it, is coming onto the scene as a super stainless option. It is roughly 50% ferritic steel and 50% austenitic steel making it twice as strong as either one as ferritic or austenitic by themselves. Fixe sells this as a more corrosion resistant version of stainless, however they did have a recall on them because they were rusting, go figure! They narrowed down the batches affected and manufacture the hangers differently now. We currently haven’t found any reports of them failing outside of those batch numbers and we really like how they perform (strength-wise) in BoltBuster tests.

However, Peter Randelzhofer put out a paper testing Fixe’s anchor PLX chain links that were in an outdoor covered climbing gym in the Netherlands and they discovered cracks near the welds.

Apparently duplex steel 1.4362 is easier to weld but duplex steel 1.4462 is better for corrosion. So the chains they tested were 5kn under the 25kn mbs in only 2 years in mild outdoor conditions.



Petzl sells a HCR wedge bolt with a HCR hanger for the low low price of a what a car costs. Bolt Products in Germany have their "Sea Water" series with twisted rod glue ins that supposedly break at 100kn and last 50 years for around €10 each. Here is some toilet reading if you think PLX HCR is interesting. However, titanium shines (metaphorically more than literally) over stainless.

Fun fact: INOX is sometimes stamped into bolts. It is a french way of saying stainless from the word "inoxydable". It could be 304 or 316 SS but it doesn't mean duplex stainless, that has PLX stamped into it.

Chapter 3 - Titanium

With a tensile strength similar to alloy steel, almost half the density of steel (56%) and platinum level of corrosion resistance, it is the "Cadillac" of all bolts. It is estimated that they can last up to 200 years (see www.titanclimbing.com).

Fun fact: titanium is the 9th most abundant element on earth and melts at 3,135F (400F more than steel). Titan Climbing manufactured the first certified titanium glue in bolt. It's a "P" shape made from one continuous rod so there is no structural weld point to break. It requires a 14mm, or ⅝ inch hole and has an MBS of 35kn. Our BoltBuster tests all were above 35kn in shear and in tension. They are about 30% more expensive than marine grade stainless and similarly priced to Bolt-Products duplex SS, but are much more corrosion resistant.

Chapter 4 - Durability

Sometimes, corrosion isn't the #1 concern but wear and tear. Jim Titt from www.bolt-products.com demonstrated in an experiment that titanium wears down about twice as fast as stainless does. He buried these metal links in a box with dry, sandy soil and had a 10mm rope run back and forth 1.6m or 5 feet through the two different metals and got these results…

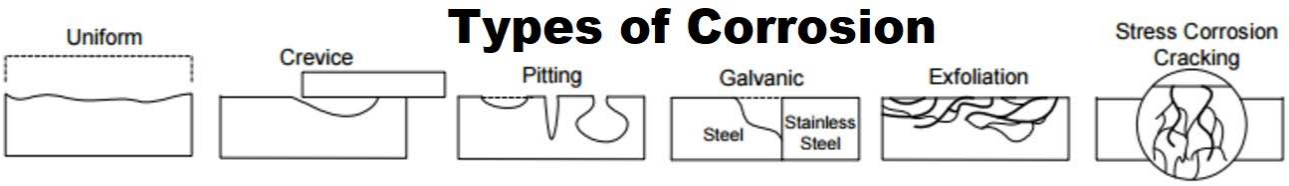
- 0 cycles - SS 8mm, Titanium 8mm
- 100 cycles - SS 7.52mm, Titanium 7.07mm
- 200 cycles - SS 6.76mm, Titanium 5.74mm
- 300 cycles - SS 6.07mm, Titanium 4.37mm
- 400 cycles - SS 5.53mm, Titanium 3.57mm
- Titanium (top photo) wears about twice as fast as SS (bottom photo)

Chapter 5 - Galvanic Corrosion

Metals are finicky in that you can't just mix any 2 that you want. They all have a different electric current and the metal with less nobility (less electrode potential) will corrode very rapidly if mixed with a higher nobility (more electrode potential). So if you mix a stainless steel bolt with a zinc plated nut or washer, the nut or washer will corrode quickly. If you mix a SS hanger with a zinc plated bolt, you won't see the corrosion happening in the hole. And SS bolts with zinc plated hangers will be real obvious. This also includes galvanized chain links on stainless bolts. So be mindful of your bolt, washer, and hangers. They all need to be made of the same metal and that metal should be at least 304 stainless if not better. See these photos as examples.

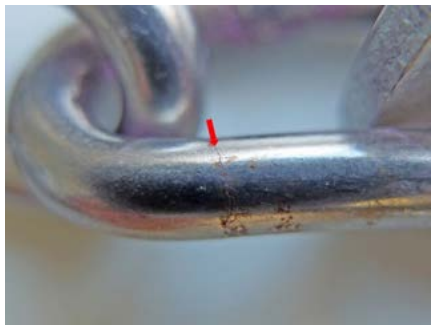
Table 1- The Galvanic Series of Metals

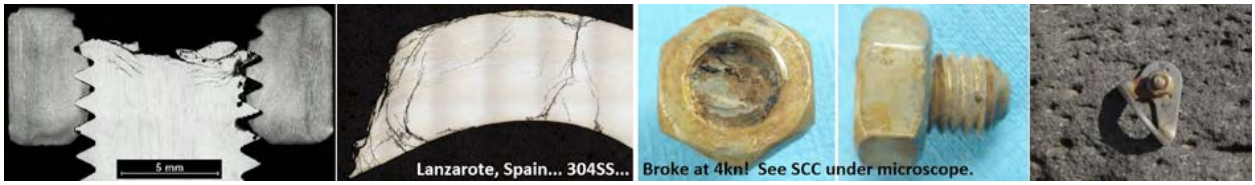
Cathodic	Least Active High Potential	Platinum
		Gold
		Carbon (graphite)
		Titanium
		Type 316 or 304 stainless steel (passive)
		Monel metal (70% nickel, 30% copper)
		Silver
		Nickel
		Lead
		Bronze, Copper, Brass
		Tin
		Lead/Tin solder
		Type 316 or 304 stainless steel (active)
		Cast Iron/Mild Steel
		Cadmium
		Aluminium
Anodic	Most Active Low Potential	Zinc
		Magnesium

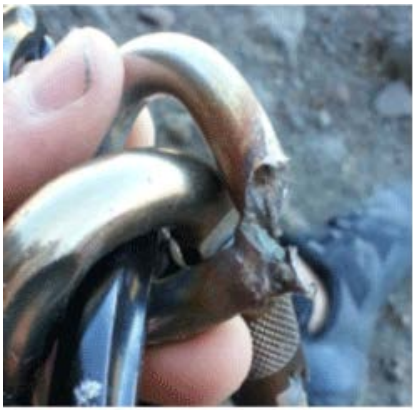


Chapter 6 - Stress Corrosion Cracking

We love the coast, but the coast doesn't love our bolts. So many coastal areas, especially in Thailand or Malta, eat away stainless bolts quickly, even 316SS. Fixe calls their 316SS "marine grade" but it is not suitable for all marine environments. Other factors that speed up corrosion can be elevated temperatures, crevices, mixed metals, mixture of high and low humidity, overhanging rock where rain cannot rinse off harmful chemicals and compounds. See the bolts failures in these photos and see how important titanium glue in bolts are in corrosive environments. This video is also gnarly!







So titanium is the best option in any areas that have a risk of SCC. It may feel more expensive but it isn't that much more. If a 100 year cost for an anchor is considered, titanium is significantly cheaper if it doesn't have to be replaced. High traffic areas will handle the wear and tear better if it had stainless steel components. Just weigh the risk of corrosion with the frequency of ropes running over the metal.

Chapter 7 - Staining

Just like skid marks on your underwear, we should avoid the same problem on our rocks. When the zinc coating on plated steel is exposed to hydrogen and oxygen (aka water) long enough it creates zinc hydroxide (similar to iron oxide which is rust). Zinc hydroxide is a white powder that forms and can leave streaks on the rock. Also when the iron is exposed, it will rust, not only making the bolt dangerous but leaving the areas looking… shitty.

Chapter 8 - Camouflage

Ideally, bolts would only be seen from the last clip in point and not be shiny bling you can see from space. In an effort to keep our climbing areas less impacted, people have tried camouflaging bolts and hangers. The biggest problem with this is that it doesn't last very long, especially as people clip carabiners to them and that metal on metal contact wears down any effort someone put in.

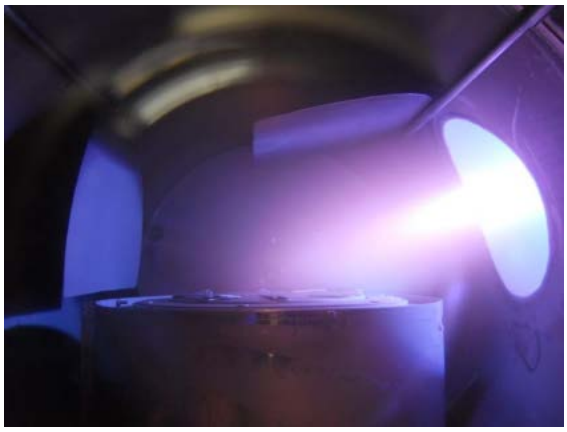
PAINT - Roughing up the metal with sandpaper and spraying them with Rustoleum at home prior to installation is one way but that process doesn't last forever if the bolt is exposed to elements or used often. You can increase the adhesion by priming it first and doing several THIN layers. Etching zinc plated hangers I hope is obviously bad as the zinc coating is super thin and when you paint wears off, you have

unprotected steel exposed. Plus zinc or galvanized metal cannot have an oil based (alkyd) product on them. The process of the galvanized layer and the alkyd creating a layer of soap is called saponification and shit starts peeling like your skin with a bad sunburn. Try painting galvanized gutters with oil based paint… I can tell you from experience as a painter… it doesn't work! If for some weird reason you care enough to install zinc plated shit but still care enough to camo them, please use water based primers and products.

Stainless isn't stoked for some etching either. Jim Titt from Bolt-Products.com explains the risk in painting stainless in this forum

"Stainless steel gains it´s corrosion resistance by producing chromium oxide which is passive and prevents further surface corrosion by blocking oxygen diffusion to the steel surface, this blocks corrosion from spreading into the metal's internal structure. Passivation occurs only if the proportion of chromium is high enough and oxygen is present, a coating which prevents oxygen reaching the surface prevents passivation from happening. The usual problem is that the coating either becomes damaged (by tightening the bolt or by karabiners) or porous due to ageing and allows water to penetrate which becomes anaerobic. We passivate all our products during manufacture and any attempt to apply a surface coating using methods such as abrading or etch priming is removing the passive layer."

Alternative Coatings - Powder coated definitely lasts longer than paint and Metolius and Fixe have some available but selection is very limited. Automotive paint can be a fancy and expensive way to camo. And Plasma coatings are next level in overkill if you really are determined to hide your bolts while having chaulk tick marks on the route! I doubt plasma will be available from your climbing bolt suppliers anytime soon when people try to save pennies per hanger when establishing routes.



Heat treating - This seems to be a fancy permanent way to mess up, I mean color, your bolts. How much can you heat up steel, stainless or duplex steel before it is compromised? If you don't know, don't do it but if you want to nerd out on it go to this forum on Mountain Project. And please don't blow torch a glue in that is already installed! The glue doesn't like that. Supposedly ClimbTech will darken wave bolts for you if requested.

Chapter 9 - Conclusions

Never use zinc plated bolts. Just the slightest scratch and the iron underneath is exposed to corrosion. And think about what holds the bolt… the wedge or sleeve at the base of the bolt. That contact point is what holds everything, and now that contact point is compromised as it is scraped against the inside of the hole. Also consider that most highlining anchors are placed on TOP of rocks, allowing water to go into these holes and just sit inside, so it is very important that a bolt can withstand corrosion.

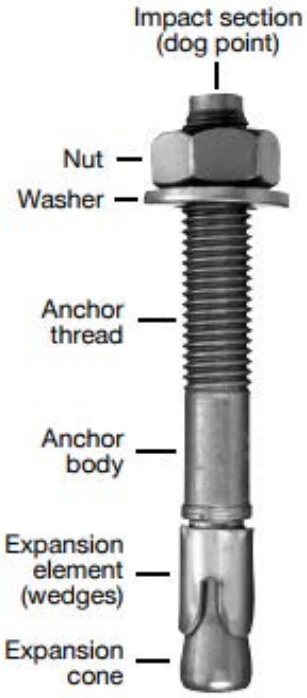
Don't mix metals or you risk bimetallic corrosion, speeding up the corrosion of 1 of the components of your bolt. And coastal areas cause excessive exposure to corrosion that even 316SS or even PLX HCR stainless may not withstand and so titanium might be your best bet. If it is a lower off anchor and will have ropes running through it constantly, stainless will hold up twice as long as titanium. Don't be cheap with people's lives and install the highest quality bolts on your climbing routes or for your highlines.

The Book of

ANATOMY

"Know what thy is shoving in thou hole."

Some bolts have 5 separate parts and others are just a single rod bent and twisted into shape. Some are welded and some have hangers built into them. Surprisingly, for being just a metal "stick" you shove into a hole, there are a lot of details that go into them as they are basically tiny machines. Know how your little machine works so you know that it will be installed correctly.



Chapter 1 - Types of bolts

Compression Bolts

Old school button heads have no moving parts. They are cut and shaped to be a little bigger than the hole and have such a tight fit that they stay in. The bolts are called split shaft, the concept is called compression bolts. The little tiny ¼" button heads are found more in blank sections of big walls where bolt ladders needed to be installed, rather than for anchors. The next size up is ⅜" and has a threaded top with a nut. We found while installing them that it takes so much work to pound them in that the nut and hanger have to be preinstalled or the threads get too damaged to put on the nut. We tested these in shear and tension on BoltBuster and found the top of the bolt snaps off before coming out, at least for a new bolt. They rarely come in stainless and is the kind of bolt that is being replaced today. They existed, so we share them here, but please don't use these. Spike bolts are similar in the fact they are bent but they are the same idea.

Nail drives and Drop ins

"Nail drives" or "Hammer set" or "Hammer Drive" or "Strike anchor" or whatever the hell you want to call it, it is a bolt that expands the sides as you smash a nail through the center. If that nail is flush, it isn't coming out. Petzl used to sell one called the "Petzl Long Life", clever name for a bolt, but apparently it wasn't popular enough and was expensive. Some are flush with hanger and prevent hanger thieves, others have nuts that hold down the hangers. Since none available today are designed for life support climbing applications, they are not certified and can be a risk. ASCA broke an off brand (AALL American) ½" in tension at only 10kn, substantially below it's MBS. ¼" strike anchors are a popular size online (not for climbing but general use) and those can break below 2kn. Drop in anchors are have a similar design but after the "nail" is pounded in with a set tool, spreading out the bottom flange, and a threaded bolt can be installed onto the threads. This video shows how they work. Short story, just don't use them, there are much better options these days.

Concrete Screws

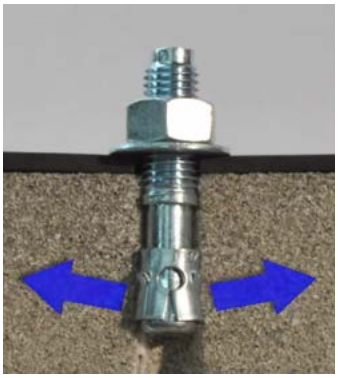
These work similar to normal wood screws. Pre-drill a hole and the threads bite into the sides of hole. The screws have a cutting thread of harder steel at the tip and the rest of the threads just follow along. This does require a quality impact drill with a ⅜" drive (NOT ¼" like so many are) as it takes quite a bit of torque to get them in, but you won't need a hammer. The hole doesn't have to be super clean like glue in bolts require, but you should blow out the dust before installing them, or you may not get it all the way in as the dust in the bottom stops it. Adding some water can help lubricate and cool when installing in harder rock and the bolt could be

compromised if trying to install this in a super hard rock. These are NOT safe in softer rock. A ⅜" bolt requires a ⅜" hole (overdrill the length by ¼") and should be used with a hanger that has a ⅜" hole even though it can feel tight getting it on there. Don't try to hold the hanger while using your drill to put the bolt in the hole. The threads can grab the hanger and spin around so fast that it could break your hand! The Titen HD's are what we use in BoltBusters and we found using a hanger with a ½" hole that it would peel off the bolt sometimes in our tension tests, albeit, above 30kn. We use these a lot in BoltBusters to anchor down our hydraulic testers and to test all sorts of hangers as they are easy to remove. We even reused the same holes (in concrete) during our hanger tests over a dozen times and it was still stronger than our hangers even though the hole was being clearly compromised. Some are concerned that after many freeze/thaw cycles these bolts will become loose over time but there hasn't been enough examples of this problem for us to be concerned about it. These are the easiest bolt to remove and replace from a bolt stewards perspective. They come in zinc plated steel, 304 SS, and 316SS. Please use a stainless that is right for your area.

Keep in mind this is a newer fad and the UIAA or ASCA or any old school bolter does not currently approve of these for the good reason that extensive science has not been done specifically for climbing. Local areas may frown upon this more than others for cultural reasons and these are NOT good in sandstone. However they have been used by several people enough and in construction and in our Bolt Busters tests to include them as a potential viable option for climbing and highlining bolts.

Mechanical Bolts with Wedges

These bolts have a small expansion clip with bumps on the side located near the base of a bolt shaft. Those bumps don't allow it to move since it is slightly bigger than the hole diameter. The very end of the bolt is cone shaped, so when the nut is tightened, it pulls the TAPERED END of the shaft up, expanding the clip. This kind of bolt is recommended only in hard



to medium rock as the contact point is very minimal. Sometimes, this bolt gets extracted so much while wrenching it tight, mostly if the clip were to slip, that the threaded rod ends up sticking up so high that it hinders carabiners from clipping the hangers and leaves significantly less bolt in the rock. If the threaded rod is protruding enough, it could also depress the gate of a carabiner open if the quickdraw was rotated upwards, possibly unclipping it or just reducing strength if loaded in that position. Never use these in sandstone or other soft rock as it can wear down the rock at the contact points under cyclic loads and become loose from the now oversized hole.

Mechanical Bolts with Sleeves

These bolts are threaded rods with a coned nut on the end. These are called sleeve anchors because the sleeve part covers the entire bolt shaft. The hex head and the shaft are one piece, rather than threads at the top with a nut. The "nut" is instead at the bottom and is coned shape so the tighter it is, the more it expands the sleeve. Therefore the hex head stays flush on the hanger rather than the rod sticking out. The sleeve also allows for more contact area and is ok to use for all types of rock although the softer the rock is, the more glue in bolts are preferred. These bolts especially need to be tightened at a specific torque, so if you don't take a torque wrench with you, practice at home to get the right feel for it before doing your project. If these become loose after placement, they could be prone to unscrewing themselves as the hanger is torqued back and forth by rope tension, and pulling out under body weight. See the buying guide for all your options at the end of the "Mechanical Bolts" section**.**

Removable Bolts

Removable bolts are great where you don't want to leave permanent bolts because it is a high traffic area, a highline that rarely will be rigged, or an overhanging sport route that you need temporary anchors to install better permanent ones. It's also great if you don't want to wait for glue in bolts to cure, because these allow you to install the glue ins AFTER you highline on the removables. The concepts are the same as wedge and sleeve bolts, however the harder you pull on those bolts, the more they grab the rock. Contrarily, removables are designed so the sleeves can be pulled up separately after untightening, allowing you to avoid the wedging action that keeps the bolt in the rock. These should not be used as a long term anchor because if they ever were to loosen, they will not be safe to use. Just like all bolts, there are some downsides. They need to be drilled perfectly because if it is too big, it just spins in the hole and if it is too small then it's a real bitch trying to remove them. If a hole is repeatedly used for a removable, mostly in softer rock, it can wear out the hole, and no one likes a hole that is worn out! If someone tries to repeat a highline, they may not know if it was a 12mm or ½" hole and that's important because they require different bolts. If on top of a cliff, a hole can get filled in with debris and need extensive cleaning. Also, in my experience, removables can look pretty mangled after a few "removings" so that's why they aren't called "reusable bolts" but "removable bolts". They can be reused but not indefinitely.

Fixe's Triplex (12mm) has a threaded rod with a tapered cone and Climbtech Legacy Bolt bolt (½") is a flush hex bolt with a coned nut on the end but is unfortunately no longer available as I have found Climbtech to be easier to remove than the Triplex. Climbtech. I like using Bolt Products' welded hangers on fixe triplex bolts so I can thread my rope directly into the hanger. See Chapter 5 below for more details on "Hangers".

If you are real experimental and rich, you can try Climbtech's fancy

removable anchor. They are designed similar to how cams are and is just a round version of ball nutz. If you bottom them out (put them in too deep), they will be almost impossible to remove. These can be great if you need a temporary bolt for establishing a route but I personally wouldn't highline on them because the flexible wire would probably be kinked after a highline session and the ½" ones are only rated for 11kn. If you use 8 of these for a highline, it should only cost over $600!!! They have ¾" and 1" sizes but we don't need to be drilling holes in our rocks that big for temporary anchors. You can drill the hole at an angle to minimize the wire kink but if you plan on using that hole for glue, then they need to be drilled properly. The inventor of these does human testing on them in this video.

Petzl now has the Coeur-Pulse a 12mm removable that doesn't require tools (assuming you already have a clean hole waiting for you). Those also are expensive but they can be used for highlining and are pretty fancy. They have a thin sleeve layer that gets pulled out of the way when you pull the trigger… aka… tooless. They require a perfect hole and so you need to use fresh 4 point bits. The fat heads on them limit how much you can clip to them but I do recommend them if you can afford them. A video on installing them can be found here.

Glue-in Bolts

And now for my favorite... glue-ins! A bolt that doesn't need a hanger that people can steal, lasts longer than just your interest in climbing/highlining, and they can have static rope directly threaded through them, eliminating 6 or 8 heavy quicklinks or steel carabiners for the lazy highliners. However, if you install threaded rod (stainless steel please), then you will need a hanger. But if you will be using an anchor for more than one highline and therefore will be pulled in more than one direction the glued in threaded rod can be a good solution. This allows the nut to be loosened and

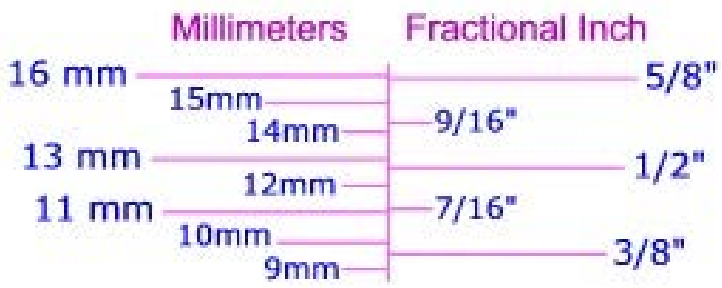
the hanger turned. However, if hangers are removed and replaced often, the threads can get damaged making that bolt worthless. Glue-ins can come as a single shaft with a welded eye on top or a continue rod. U-shape (or staples) are a rarely used glue in, requiring 2 holes (one for each leg) which is more impact on an area and rare to see as they are prone to unclipping carabiners. Glue always comes in two parts and is very important to mix it right as most glue in failures is a result of improper mixing. But if mixed right and the hole is dust free, it can offer some of the strongest anchors available.

Mechanical bolts are just pushing on a fraction of the sides of a hole but glue-ins grab 100% of the hole and that is especially important in softer rock or layered rock. The glue gets into the pores of the rock and makes for a bomber anchor compared to a wedge. It also keeps water out of the hole preventing corrosion where you can't see it. They are much more technical to install and can cost more (if using hilti epoxy) than a mechanical bolt, but they will last a lifetime therefore leaving less of a long term impact.

Do not use glue with mechanical bolts. You don't get the best of both worlds, you get the worst. The glue will only sit on the outer sleeve and not attach to the actual rod that holds the hanger down. The glue could prevent the anchors from expanding. If the hole is big enough for glue, the wedge won't wedge. If the hole is the right size for the hole, there is no room for the glue. The glue can also clog the threads. I'm not saying that a mechanical bolt is going to fall out of the hole easily if you use glue, but that is not how they are designed. Don't try to get fancy!

Chapter 2 - Girth Matters

Back in the day, ¼ bolts were used and yikes. Now they are all getting replaced. It is very common to have a 10mm or ⅜" bolt for climbing and 12mm or ½" bolts are the standard for highlining since they can potentially see a lot more force than the ones used for climbing. If bolting in softer rock a 16mm or ⅝" bolt might be better, not to benefit from the strength of the bolt, but because a bigger bolt can hold the rock better. And if the rock is soft enough, you will want those fat bolts to be glued in.



Drill bits are important to get right. Although ½" = 12.7mm, you CANNOT interchange 12mm and ½" drill bits if you use fixe triplex removables. Sometimes 12mm and half inch bits can be interchanged for wedge or sleeve. And 12mm or ½" bits are fine for glue ins that require either one. You just don't want to put a ⅜" glue in bolt in a ⅝" hole. Too much of anything is bad.

Chapter 3 - Length Matters

Your length depends on how hard you are… I mean, how hard the rock is. The harder the rock, the harder the hole, so don't worry about deep penetration. 2.5" or 55mm is fine for hard rock. The softer the rock the softer the hole and so you want to get it in as deep as you can. 6" or 150mm is important for softer rock.

Remember, mechanical bolt lengths describe the entire bolt so keep in mind how much will be below and above the surface. Glue ins are often measured by just the section that goes inside the rock. It doesn't matter how long you think it is but how deep it actually penetrates!

Chapter 4 - Washers

Washers distribute the pressure over more of the hanger (serious rocket science material here!). They might not be fancy but they are important. Some bolts, like Powers 5 piece rawl, comes with the washer. They are also very important if chain links are used instead of hangers (which is not an ideal method). In BoltBusters, we tested with and without washers on ½" holes on ⅜" holes. The hangers would peel off the bolt! Use the right size hanger

with the right size bolt, but also use washers when applicable.
The most common mistake when using washers is to buy the shiny cheap ones at the store. **Don't use zinc washers!** Stainless and stainless need to be together or that washer will rust quickly.

Chapter 5 - Hangers

We aren't talking about the airplane kind or the closet kind, but climbing hangers… and they are not all created equal.

The **bolt holes** generally come in ⅜", 10mm, ½", 12mm and CMI makes a rare hanger with a ⅝" (16mm) and if you ask nicely, Jim Titt from Bolt-Products sometimes makes his awesome welded hangers in the bigger size. It's important to use the right size bolt with right size hanger, otherwise it floats around the bolt and can twerk it wrong. And we shouldn't be twerking around our holes! We have also had many ½" hangers peel off our ⅜" bolts (under quite a bit of force).

The **hanger strengths** vary on normal size hangers around 25kn but Fixe's stainless ½" and 12mm hangers are 30kn certified with a 44kn ultimate breaking strength. We have occasionally achieved up to 60kn on Fixe's PLX and SS hangers in our BoltBuster tests. CMI's ⅝ hanger is rated the as one of the strongest hangers at a whopping 44kn but broke in BoltBuster at 37kn, 15% below the MBS because they use a cheap mild steel that they powder coat instead of using Stainless steel which would be stronger and last longer.

The **materials** that hangers are made of also vary. I don't know why aluminum hangers exist, but they do. They are not as strong and it mixes metals. Fixe sells PS (plated steel) and saves very little money in exchange for strength

(about 10kn less) and longevity (don't use zinc plated anything!). These are probably intended for indoor use such as climbing gyms. As amazing as the large CMI's hangers are, they are just powder coated plated steel so that really kills the stoke I had for them, even before they broke a lot lower than their claimed 10,000lbf. Stainless steel hangers are the only kind of materials that should be used for hangers since we should only be using stainless steel bolts (or titanium but those don't come in a mechanical bolt so you don't need a titanium hanger). Fixe and Petzl both sell 304 stainless hangers. Fixe also sells a 316 stainless hanger and a PLX hanger which we have found to be the strongest on the market in BoltBuster.

Bolt-Products makes a 12mm (the size of the bolt hole) hanger out of 8mm stainless rod so rope can be threaded through. Not ideal for climbing anchors as it would wear the metal quickly but eliminating the need for quicklinks in highline anchors since ropes cannot be threaded directly into normal sharper hangers. The downside is that it is welded, increasing the risk of SCC (stress crack corrosion) in certain harsh environments, and the weld point is a risk point of failure (though unlikely). They are rated for 45kn and we could NOT break them in tension at 42kn and in shear at 52kn (bolt heads snapped off first) so we are very happy with strength. They are a great solution to be able to run the rope directly in the hanger, which you cannot do with a normal hanger. In fact, the only solution for direct ropes if using mechanical bolts other than chain links.

Chainlinks are commonly used as a cheap "hanger" that a rope can be threaded in for highline anchors and is generally rated for 30kn to 70kn. Basic new steel chains used on ⅝" bolts that we tested in sandstone broke in the 60kn range when they broke. The bolt broke more often. One downside is that they rust because

no one buys high quality chain links. The other problem is they don't sit flush with the rock, meaning they pull on the bolt about a half inch above the rock, creating a lever that greatly reduces the strength of the bolt. Also, if you see chains, there is a 90% chance there is a zinc plated bolt in the rock since price was the obvious deciding factor when installing the anchor. One chain link cannot be used, but instead 2 or 4 links need to be used to get a proper orientation and consider the more links, the more points of failure there are. These chain link bolts should only be used to pull shear (sideways) and should not be used to pull a bolt in tension (straight out) because it deforms the chains significantly even though we got around 50kn before final destruction of the chain happened. We do not know the strength of zinc plated chains after corrosion has begun.

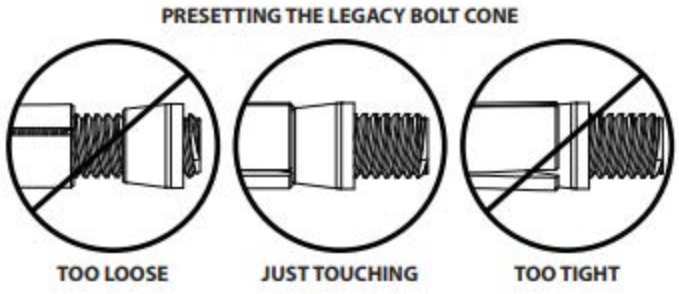
The Book of

MECHANICAL BOLTS

"The more you twist the head, the more the nut gets sucked up."

So mechanical bolts aren't rocket science. If you have the right size hole, and a quality bolt made of stainless, the basic idea is that you smash it in and tighten it. A wedge gets sucked into something that expands. You can have a rod with a flared end or wedged nut, and if the part that expands is big enough, it's no longer a plain ol' wedge bolt but magically transforms into a sleeve bolt. However, like everything, it's what they don't tell you that gets ya… so let's go over the little nuances of each type of bolt that will help you install a safe mechanical bolt..

Chapter 1 - Sleeve Bolts

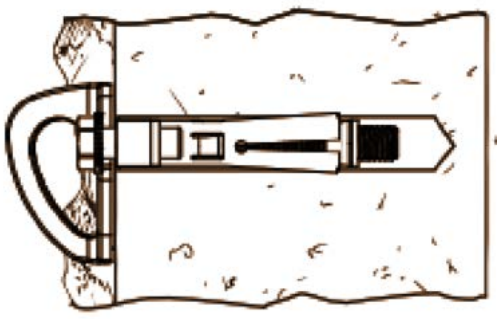


Smash them in and tighten them. It's not much harder than that, but here is some stuff you need to know. It is important to install the hanger onto the bolt BEFORE hammering it in. If you forget, then you may not be able to pull it back out to get the hanger on. If you can partially remove it like the Power-Bolt, then you risk debris getting into the threaded cone at the bottom. If you take the nut off of Fixe's Triplex bolt, then the whole rod can fall into the hole and probably deep enough to where you can't get it out because there would be no way to grab it. So, install the hanger of your liking to the bolt BEFORE hammering it into hole. Place the coned nut, that is at the bottom, so it is just touching the sleeve but don't pre-expand the sleeve (see pic above).

Now it's time to hammer it in (the hole is clean, right!?). If it goes in really really easy, you may have a hard time getting it to tighten because the entire bolt and all its parts are spinning in the hole. If it is a bitch to get in the hole, then your hole is too small and you risk breaking or compromising your bolt, and the harder it is to get in a removable, the harder it will be to get it out!

Then tighten it. All bolts have a specific torque pressure they require to achieve the ratings that the manufacturer claimed. Torque wrenches are not expensive but can suck to take on a long hike. If you don't use one on the mountain, at least use it on some practice bolts at home in your backyard so you know what it should feel like. If 25 foot lbs of torque is required and you have no freaking clue what that feels like, use a small to medium wrench and pull until your face scrunches but not so hard that you grunt. If you don't tighten it enough, obviously the risk is that it could come out. When I tensioned bolts from 25 to 35 torque lbs, I was shocked how much umpf I had to give it. There is a limit, like everything, that if you really really tighten it that you compromise its integrity by breaking the bolt or stress cracking it. A fun experiment is to try to pull out your test bolts after hardly tightening it at all. It is amazing how well they hold. However it is important that they are properly tightened.

Hangers want to be a certain direction depending which way you pull them. You don't want to randomly place your hanger and then, when tension is applied to it, forces it to spin to the correct orientation while under pressure. If it doesn't spin, then you are pulling on that hanger in a very unfavorable way, just as if you pulled against the gate of a carabiner. It can reduce the strength. Hangers broke lower in our tension tests on BoltBusters than in shear. Put a carabiner on the hanger and pull on it in the direction it will be used. And on highline anchors, remember that the furthest outside bolts are going to be pulled diagonally towards the master point, and not necessarily the same direction as the highline.



Keep in mind that if your hole is too shallow, the bolt obviously won't go in all the way, but that means the hanger will be spinning because it isn't secured to the rock.

That doesn't mean it will blow out the hole if you use it, but it is considered sloppy and I don't know if I would trust a bolt that I knew nothing about if the hanger is loosely spinning. If you really goofed, and it is sticking way up, then it could leverage the bolt, breaking it at a much lower force.

Sleeve bolts are better for softer rock because they have a larger surface area and can open the split sleeve wider than just a wedge bolt with a small clip at the end of it. The softer the rock, the deeper and bigger you will want your bolt. There is no downside to using a sleeve bolt in hard rock so it is a good idea to use them unless you want marine grade 316 stainless, which is hard to come by in a sleeve bolt.

Chapter 2 - Wedge Bolts

The real difference is the size of the expansion clip at the base of the rod. There is no real reason to use wedge bolts over sleeve bolts other than it's easier to find 316SS, as most sleeve bolts are 304SS. So if you have an area that is prone to corrosion and have hard rock (as it's not a good idea to install wedge bolts in soft rock), then these might be the right choice. But if the area is high risk of corrosion, you might as well put in titanium glue in bolts to make sure that it lasts.

To install, start in the same way as the sleeve bolts by putting the hanger on the bolt before hammering. These too require a specific torque. Tighter isn't always better. Be sure to line up your hanger with the direction you will pull it and wrench it down. The rod will stick up higher than the nut after you torque it so start with the nut as high as possible without hitting it with the hammer. Make sure the wedge is expanding immediately and not sliding up the hole walls as you tension the nut 20 turns, leaving very little bolt left in the rock.

Chapter 3 - Are you an Innie or an Outie?

Ok, so bolts don't have innies as much as flush hex heads. A hex head attached to the rod sucks up the nut at the bottom like a good cough will do to yours! The rod/shaft doesn't get any higher the more you tighten it; all the magic happens in the hole. Only sleeve bolts have this design.

But then there are outies where the rod/shaft is being pulled out of the rock as you tighten the nut. This can be on some sleeve bolts, but it is on every wedge bolts. The nut should be installed when you hammer it in, but you don't want to hit the nut because that means you are putting all the force on the threads and that can damage them. However, you don't want the rod sticking way up when you are done, so you want to start the nut as high as you can get it, without actually hitting it.

Chapter 4 - Hangers matter

The hanger that the bolt is securing to the rock, is as important as the bolt itself. Many hangers are rated for 22kn to 25kn just like the carabiners climbers generally attach to them. However some hangers have broken past 50KN as seen in our BoltBuster tests. It is nice to have a hanger that is similar strength to the bolt it is attached to, otherwise you could be leaving some strength on the table since the weakest link will break. Hangers made from round stock can have rope threaded directly into them for highline anchors. The round stock generally has less of an impact as they don't shine quite the same way as a flat hanger, so that can be a benefit to using them in climbing, but is not ideal for climbing anchors as they could wear down quickly if ropes are constantly running inside of them. Offset hangers are designed for anchors so your rings or quick links added to them allow the rope to go sideways and not get smashed against the rock. Additional hardware should be added to hangers for climbing lower off anchors.

- Fixe Hardware has some SS hangers that have a Ultimate Breaking Strength up to 44kn or 10,000lbs, and are CE/UIAA Certified for 30kn. In BoltBusters, we have confirmed the ultimate breaking strength to be a common result. The PLX hangers are really strong! They come with hole sizes 10mm, ⅜", 12mm, ½" from $2.95 to $3.95. DON'T BE A CHEAP ASS AND BUY THE PLATED STEEL HANGERS. THOSE ARE FOR INDOOR GYMS.

- Petzl has a 316SS hanger that is about $4 each but they are only rated by Petzl for 25kn.

- CMI has a hanger for a ⅝" bolt and is powder coated steel. Since we can't mix metals and shouldn't use anything but stainless, these probably

shouldn't be used. We also broke them at 15kn below MBS. And they are $10.35 each! Not recommended.

- Bolt-Products has a hanger made from a 8mm 316SS (A4) welded rod for a 12mm bolt at a price of €5.20. These allow a rope to be threaded directly inside of them. These are my favorite hanger. They work great with Fixe's Triplex Bolts or any 12mm bolt that you have. I have to drill the hole slightly bigger if I want to use them on ½" bolts. Team Tough is the US distributor for Bolt-Products.

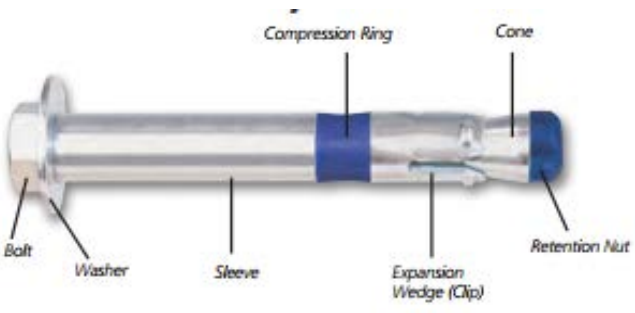
- Bonier has a hanger without sharp edges so that a rope can be threaded through, which is ideal as a highliner since we won't have the rope running over this surface wearing it out like a climbing anchor. Comes in 304 and 316SS

- Bonier also has an omnidirectional hanger for 12mm or ½" bolts, though power bolts will NOT work with it because this gets set on a bolt after it is installed. Certified for the construction world but possibly a great highline hanger for lines pulling straight out of a wall.

- Chain links require many washers between the link and the rock to raise it high enough so the second link doesn't grind on the rock. This means all the pressure is being put towards the top of the bolt instead of the base, significantly reducing strength. Also, they should not be pulled in tension, so if you put your bolts in the middle of a cliff face to be pulled directly outward, chain links should not be used. Keep in mind these don't work for sleeve bolts (because of the flush heads) so then wedge bolts are most likely going to be used which isn't the best option but OK if stainless. The one good thing about them is that they can have a rope threaded in them eliminating the need for quicklinks in a highline rig. However, chain links you may see at highlines are probably zinc plated because cost was the determining factor when installing them. 1st Chain Supply also offers ½" made from 316SS but it is 14.90 per foot with a 10 foot minimum.

Chapter 5 - Ugh, why is it doing that? (FAQs)

- Why is my sleeve bolt just spinning and not getting tighter?
    - The hole is probably too big, the entire bolt and all its parts are spinning inside. The nut at the bottom of a sleeve bolt needs to stop spinning, so give friction to the nut by pulling up against the sleeve while you tighten. This is done by pulling up/over on the hanger. If it comes out too much, after you get some progress, hit it back down flush against the hanger and rock and finish tightening it.
- Why is the wedge bolt rising as I tighten but not getting tighter?
    - The clip at the bottom is either spinning with it or the wedge at the bottom is lifting the clip instead of expanding it. The clips commonly have 2 bumps on them to give some friction along the rock and so it shouldn't do this, but if that's your problem then try to pull up on hanger while tightening but if you try to hammer a wedge bolt back down because it got to high/extracted, it only knocks the wedge out of the clip and you are more or less starting all over. Hole size is pretty important here.
- Why is it snug and tightening but won't get solid?
    - If you are sure the sleeve or clip is expanding and it is snug but not increasingly getting tighter, then the rock is shit and it's expanding the rock (I have had this happen to me before in Iceland).
- What are those plastic parts on the sleeve bolts?
    - Sometimes there are spacer sleeves or bushings or compression rings that are made out of plastic. These just separate the parts and



it's not holding any force but helps with installation. The powers spec sheet states, "The Power-Bolt is also designed to draw the fixture into full bearing against the base material through the action of its flexible compression ring. As the anchor is being tightened, the compression ring will crush if necessary to tightly secure the fixture against the face of the base material." There is also a plastic star shape below the nut on some bolts and that helps with the loose nut syndrome, something we all try to avoid! Leave them on there, they help. Don't worry, they aren't the parts that hold the bolt in the rock.

- The wedge bolt is secure but the rod sticks up higher than the hanger, is that ok?
    - It cosmetically looks bad and leaves any wandering climber curious as to how much bolt is left in the rock. If you are absolutely sure you have a sufficient amount of bolt left in the rock, and the wedge and clip are NOT just below the surface, then it is going to hold. If it sticks out too much it could hurt someone or be an unclipping hazard. I recommend loosening the nut, hammering it in again and trying to get it to seat deeper. Just having the tip in the hole isn't going to satisfy everyone involved!

Chapter 6 - Real life shit

This video is of a bolt breaking during a highline whipper. Andy Lewis set up a highline for an Alex Mason's Red Bull eclipse shot and had to use some existing shitty bolts. They were shitty zinc plated bolts that corroded enough to snap during approximately a 5kn whipper which was spread out over that 3 point anchor probably only putting a maximum of 3kn on that bolt.

Chapter 7 - Buying Guide

As nice as it would be to write in this book, “Just use this 1 bolt”, there is no perfect bolt as each has pros and cons. We want you to know HOW to buy bolts and NOT tell you WHAT to buy. Consider the following when reviewing bolts you see online...

- Length is TOTAL bolt length for mechanical bolts. If you have a 4 ½” bolt, you may only end up having 3.75” embedded in the rock when you are finished.
- Some bolts are certified with EN 959:2007 certification or CE/UIAA or some construction certification. And some are not. Go with a reputable company in either case.
- Don’t buy zinc plated or plated steel or galvanized bolts. If you can’t afford stainless, don’t install bolts. PLX stainless is even better.
- Read the spec sheets and know what the torque specs are (how tight that bolt is supposed to be wrenched down).
- Be sure your hanger is made of the same metal as your bolt so you don’t get galvanic corrosion.

These companies sell mechanical bolts that I would take a whipper on.

BoltProducts is based in Europe and Team-Tough is their distributor in north america. Their products are quality. The only mechanical bolts they sell are wedge bolts.

Fixe Hardware has great selection including Powers sleeve bolts but unfortunately they sell PS (plated steel)... WTF. Their PLX selection is growing too. Manufactured in Spain sells out of US.

ClimbTech sells Powers sleeve, wedge and removable anchors. Unfortunately they also sell PS Powers!?!? US Based.

Vertical Evolution has a single mechanical bolt option that comes in 8mm (too small), 10mm and 12mm… in 316SS or galvanized??? Most of the bolts on their sight are glue in bolts. Based in Italy.

Climbing Technology has great selection of HCR (PLX) and 316L mechanical bolts. Based out of Italy and France.

Raumer sells wedge and double wedge of all sizes. Based in Italy.

Petzl sells quality bolts but they aren't cheap. Sold everywhere.

Rap Bolting is US distributor to Titan Climbing (they only sell glue ins and are based in the UK) and Rap carries a few mechanical bolts. They carry SS powers but only the short ones. Good for granite, not for softer rock. They also carry some wedge anchors.

The Power-Stud was a great 304SS wedge bolt that is about $3 each and is very accessible and comes with ss washer and nut. In our Bolt Buster shear tests, they will snap at 60kn, higher than almost every hanger. Not good for soft rock.

What NOT to Buy

I am NOT convinced Keith Titanium makes bolts that are OK to use but my OCD won't let me exclude it from this book if I'm attempting to make a complete guide to bolts. I tried buying some but they supposedly don't sell these in the US and after researching the product this is what I found. Someone couldn't screw on the nut when they bought it because the threads were poor quality. The website claimed UIAA approved and the UIAA took action and it is no longer on their website. It is not certified to EN959 either. Tested by a third party said this is NOT a titanium alloy like the website states but is commercially pure and not an alloy. The nut and bolt threads appeared cut and not rolled (rolled is stronger and holds up to fatigue). The wedge piece is floppy so a large portion of the bolt gets pulled out of rock when tightening leaving a shallow embedment depth.

The Book of

Climbing Anchors

"It's important to stay safe whilst getting off"

Yippee, you are at the top! Now what. You will find climbing anchors that are designed to be top roped on, lowered off, or just a pit stop before going up the next pitch. Anchors need to be redundant so they will have at least 2 bolts, but the configurations of hangers, chain, quicklinks, rings and lower offs are endless. Let's look at some common types.

Top Access Top Rope Anchors

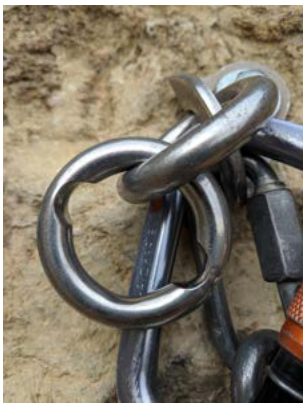
Routes that offer climbers the luxury of walking to the top of the climb to set up and take down the rope allow route developers to install simple hardware, aka just the bolts. Most TR anchors set ups are two bolt/hanger combos with the assumption that a climber will use their own gear to set up an adequate anchor. Some things to consider:

TR anchors should balance security of the climber while avoiding creating excess rope drag being too far from the edge. If you place an anchor several feet away from the edge it will be much safer to build an anchor but it will be harder to create one where the master point extends over the cliff edge, making rope drag a concern. In some areas there is a boulder or tree that climbers can tether to to safely access the anchors. Another strategy is to place the bolts farther back from the edge with a large space between them. While this requires climbers to bring longer anchor building materials to create an equalized anchor over the edge it allows them to practice better edge security. Keep in mind in most multi-pitch and big wall anchors there will only be two bolts since the follower will be able to remove the gear the leader installed.

LOWER OFF ANCHORS

We all know it is important to still be able to get off even when high. Of course you can still set up top ropes on routes that you cannot walk up to or more importantly walk off, but they require a bit more permanent hardware if route developers don't expect climbers to leave their own gear to get safely back to the ground. Whether used for multi pitch rappel routes or single pitch climbs, and the ethics of the area, there will be several different lower off anchors.

Developing enjoyable safe routes with the proper bolts takes a lot of skill and experience. Fortunately, lower off hardware added to bolts is much simpler allowing any climbers with basic understanding of hand tools to be part of the future route maintenance. The major consideration in lower off hardware is rope wear. Smart developers make sure that the components that will see wear are easy to replace. Ideally climbers who will top rope all day on a route will use their own gear at the anchor, instead of wearing out the permanent hardware, but its good to anticipate high use on the permanent hardware.



Titanium has become popular as photos of corroded bolts float around the internet. However, keep in mind that stainless steel holds up twice as long with ropes running over it. So if you set up a popular lower off anchor, unless you are in Thailand or right next to the ocean, steel chains, rings and hooks will handle the rope abrasion better. Just be sure to use ***stainless*** chain, rings and hooks, not only for corrosion resistance, but also so it doesn't stain the rock with rust or zinc streaks like zinc coated anchors. See the Book of Metal for more about this.

Open VS Closed Systems

Closed systems require the rope to be untied from the climber and threaded through the lower off or rappel. Examples include chain, rings and quicklinks. This is very common on multi-pitch rappels since you have the ends of the rope handy and accessible. This excellent article and video from the AAC shows the method to reduce the risk of closed system anchors when installing after single pitch climbing.

Open system lower offs allow the climber to put the rope into the permanent hardware without untying. Examples include carabiners, mussy hooks and rams horns.

While both systems have their place, open system lower offs are gaining popularity in single pitch sport and trad climbing areas that see a lot of traffic.

Horizontal vs Offset

Horizontally aligned bolts are a very common set up. Two bolts more or less at equal height a least a hand width apart. If traditional hangers are used at least two links are needed to orient the rope parallel to the wall, not pinched into the wall. Some manufacturers make horizontal hangers to address this issue. Keep in mind that if the two rap rings or quick links are spaced out and don't come to a single point, it can create twisting in the ropes.

Offset anchors place all the force on one bolt with a second bolt backing up the first in case of failure. The force can be on the top bolt and backed up by the bottom or the main system on the bottom with the top one attached with a chain of some sort. Even though a single climbing bolt can easily withstand up to 20 times the forces generated in a rappel or top roping session, redundancy is very important at anchors. Not having to place bolts on a horizontal plane allows the route developer much more freedom in bolt placement, especially critical in rock of variable quality. Sometimes they are connected to each other and sometimes they are not

COMMON COMPONENTS

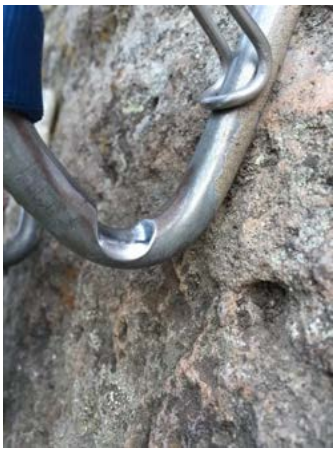
Quick links: Used either as a connector or the primary lowering point. Ensure that you use quality quicklinks as not all metals are created equal and threads, the part that holds it together, can affect the strength of the connection. Rolled threads are stronger than cut threads. Stainless quick links will resist corrosion longer. Size matters! A quality ⅜" or 8mm link is the minimum that is strong enough and won't compromise your soft goods with a narrow bend radius. Pro Tip: Make sure the gate of the quicklink is wide enough to fit over your other hardware. Guess how we learned why that was important!

Rings: Several climbing manufactures offer welded rings specifically designed for lower off/rappel anchors. They are often sold attached to hangers but can be purchased separately and connected with a quicklink. Unlike quicklinks, rings are able to spin and spread wear from the rope on more than two points. Avoid the rolled aluminum variety as they are much weaker and more susceptible to wear.

Chains: Chains are used to extend the master points to minimize rope drag or connect other anchor components, even though the last link of chain is common to lower off from. Chains can also provide extra clip in points for building anchors and hauling. While harder to source and more expensive, long link chain has more area to clip carabiners. Stainless is preferred but since chain is usually easy to replace other types of steel are often used. Not ideal as these often leave streaks of rust and can discolor the rock as the coating dissolves. Down sides of chain include: high visual impact, wasteful as you cut chain to length and heavy to carry when developing. Designing anchors to avoid chain saves a lot of headache.

Captive Eye Carabiners: Having fixed gear bootied sucks, use captive eye carabiners to keep "would be gear thiefs" honest, you know who you are! There are several carabiners that you can add a pin to secure them. It is also possible to buy carabiners with an integral eye that require a quick link to add them to your anchor set up and quicklinks can be glued shut.

Mussy Hooks: These hooks allow you to drop your rope directly into them. Slip hooks for towing are commonly used, these generally have really poor gates that fall off or get sharp. Climbtech offers a great option with a climbing style wire gate. They can be attached to bolts with just a quicklink.

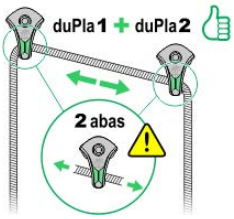


Fixe Super Shut: These hooks have an eye so it can be bolted in directly and carabiner like gate. They are limited to a ⅜" bolt and there is not a substantial amount of material so it can be worn quickly if on a popular route

Ram Horn or Pig Tail: These are simple and bomber and can be twisted onto most hangers or glue ins so there are many ways this can be part of a combo. They can be used as a single master point and changed quite easily when worn or even installed as a pair for a redundant beautiful bend for your rope.

Monster Hook: This fancy glue in is designed to be a single point lower off. Two of these could be placed next to each other but would cause rope twists. Probably better as an offset anchor. Difficult to change if worn, and confusing to anyone who hasn't seen them before, but very clever!

Bonier duPla:



A note on Bonier's fancy anchor hangers. I love the idea of a hanger a rope can be threaded into as a highliner, but for a climbing anchor 2 need to be placed in order to be redundant and if you put them side by side you might get some gnarly rope twist action going on! And if they wear down there are sharp edges against the ropes.

Remember to never mix metals!

DIY Anchor Setups

V SETUPS can have anything at the bottom. Rings are very common, rams horns can be threaded through and Mussy hooks can be installed on there.
Best use: extending master points over edges or equalizing to a single point (equalizing bolts for lower offs is not critical)
Cons: expensive, high visual impact, must bring variety of lengths for install, chain links won't hold up to wear if lowered off on frequently, most inefficient anchor design

Open French - Rope weights top ram horn and is backed up by the lower carabiner.
Best Use: single pitch climbs, easy to maintain, one of the safest and most redundant vertical open systems
Cons: uncommon, aligning backup carabiner can be tricky so it doesn't have risk of opening

French - Rope weights top quicklink, or ring, and is threaded through the lower one to back it up. One of the safest and most redundant closed systems.
Best Use: multi pitch rappels, single pitch climbs
Cons: closed systems require more effort to install your rope

Vertically Backed Up Ramshorn
Best Use: single pitch climbs, simple and open
Cons: master point is only partially redundant, chain has higher visual impact

Double Mussys
Best Use: High use lower offs
Cons: Mussy hooks are not stainless, other than climbtech's hooks most Mussys have bad gates

Chains to Ramhorn
Best Use: retro fitting existing horizontally placed bolts
Cons: highest visual impact, master point is not redundant

This chart below comes from [Matthew Markell] and is also a good comparison between some anchor types.

Anchor Comparison

	 Authors Preference					
Name	Vertical Inline Ramshorn Setup	Horizontal Mussy Hook	Hybrid Inline Vertical Setup (Photo not exact setup)	Alternate Ramshorn "V" Setup (Glue Ins not in photo)	"French Ramshorn" Hybrid	Inline French Anchor
Description	Two Glue Ins placed vertically connected by 8mm 316SS Chain and one Ramshorn	Two Glue Ins placed horizontally. with 2 CT Mussy Hooks. 2 SS QLs. All but Hooks in 316SS	Two Glue Ins placed vertically with CT Mussy Hooks. 2 SS QLs. All but Hooks in 316SS	By using chain sets for the bolts, the cost of the "V" setup in SS can be reduced.	Two Vertically placed Glue Ins with a top Ramshorn and lower SS carabiner (QL preferred but not pictured) All 316SS	Two Vertically placed Bolts with 2 QLs and 2 Rap Rings or Links
Costs	1 x BP Bolt w/ Chain =$8.44 1 x BP 8mm Bolt =$4.36 1 x Ramshorn =$6.04 Total = $18.84 Replacement Cost = $6	2 x CT Wave Bolts = $8 2 x SS QLs = $12 2 x CT Hooks = $9.60 Total = $29.60 w/PS QLs = $21.53 (not as good) Replacement Cost = $10	1 x BP Bolt w/ Chain = $9.60 1 x BP Twist = $4 2 x QLs (SS) = $11.52 2 x CT Hooks = $9.60 Total = $34.40	2 x BP Bolt w/ Chain = $16.88 1 x Ramshorn = $6 Total = $22.88 Replacement Cost = $6	2x BP Bolts = $8.72 1x Ramshorn = $6 1x SS QL = $6 1 x 10mm SS Biner = $8 Total =$28.72 Replacement Cost = $6	2x BP Bolts = $8.72 2x SS QL = $12 1x SS Link = $5.60 Total = $26.32 Replacement Cost = $6
Pluses	All 316SS components that are rated. Best Price. Ease of Use. Flexible placement. Long link chain easier to clip and/or grasp. Lowest replacement costs. ($6)	Fairly Straightforward Install. Price ok if you go with PS QLs. Low Profile. Ease of Use. High Wear Resistance. Easily replaced when worn. ($10 cost)	Mostly 316SS. Placement benefits of vertical orientation. Placement also gets hooks next to one another reducing twisting (still an issue if rock is lower angle). High Wear Resistance.	Now completely 316SS and rated components.	All 316SS Drop In loweroff Flexible Bolt Locations	All 316SS Flexible Bolt Locations Minimal Visibility Good Multi Pitch Setup
Minuses	Less familiar to US climbers but quickly learned.	Limitations on both locations as they need to be close to each other to avoid rope twisting and increased wear on hooks. Rock band must be GOOD. PS QLs can rust adding corrosion issues. SS works but adds to costs.	Cost is higher vs Ramshorn. Cost could be reduced by using PS QLs but contact corrosion on glue ins becomes issue long term. Savings would be $8 but PS QL also typically not as high quality.	Still not as flexible in placement options but not bad and helpful when placed where a "V" might be the better option.	Less Familiar to US climbers.	Expensive Requires Untying

Pre-made Anchor systems

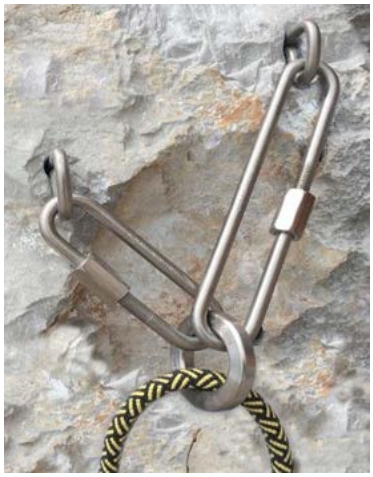
Fixe Anchors (partial list)



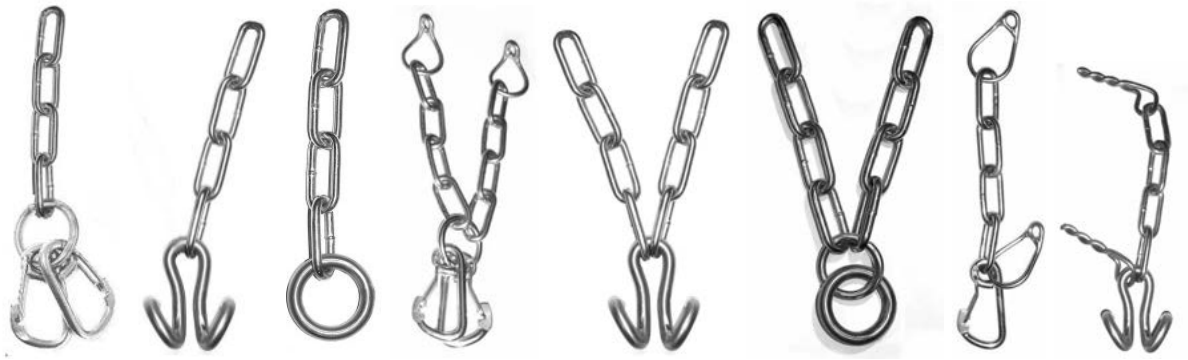




Titan Anchors US Distributor


Bolt Product's Anchors US Distributor (partial list)

Vertical Evolution Anchors (partial list)

Raumer Climbing Anchors (partial list)

The Book of

GLUE IN BOLTS

"Some slip right on in, some you have to force, but either way it is just a sticky mess"

Glue in bolts are better in many ways but installation is trickier. They are stronger, last longer and more convenient to use (not install) since many don't require hangers. Water never gets inside the hole so if there was corrosion, it's on the part you can see and inspect. However, the holes have to be really clean, the glue has to mix right AND fill up the whole hole… all without getting it everywhere. Also, the bolt isn't adjustable later so it better be right. They can last a long long time and can be the best option, especially in soft or layered rock, so let's go over what you need to know so you can do it like a pro.

Chapter 1 - Bolt Types

I suppose you could glue anything inside of a hole, but if you are installing glue in bolts, I assume you are thinking long term and want to do it right. It is NOT recommended to use mechanical bolts with moving parts like we described in the last section. The glue wouldn't grab the right parts, like sitting on the sleeves and not the actual stud, and the mechanical parts get gummed up by the glue and aren't free to do what they need to do. And any properly placed mechanical bolt is going to fit the hole so tightly, there wouldn't be any room for the glue and therefore push it all out. There are bolts specifically designed for glue, so let's go over those options.

U shape bolts

Also called staple bolts, these are almost never used in highlining as they require two holes and have twice the impact. And consider that the 2 legs rarely share the load so you don't necessarily get 2x the strength. If one leg goes, so do you. AND… when holes are drilled that close together, it could weaken the rock. The benefit to these is that they do test stronger when being pulled straight out than the P shape

bolts. These have the potential for one side to open the gate a carabiner if things are pulled around, probably the main reason these are not used on climbing crags, but rather via ferratas where the hardware is fixed. Please don't buy any ol' U shape bolt from the hardware store! If you must use them, please use Titan's because they are very corrosion resistant and rated for 15kn with an MBS rating of 30kn but commonly break above 50kn.

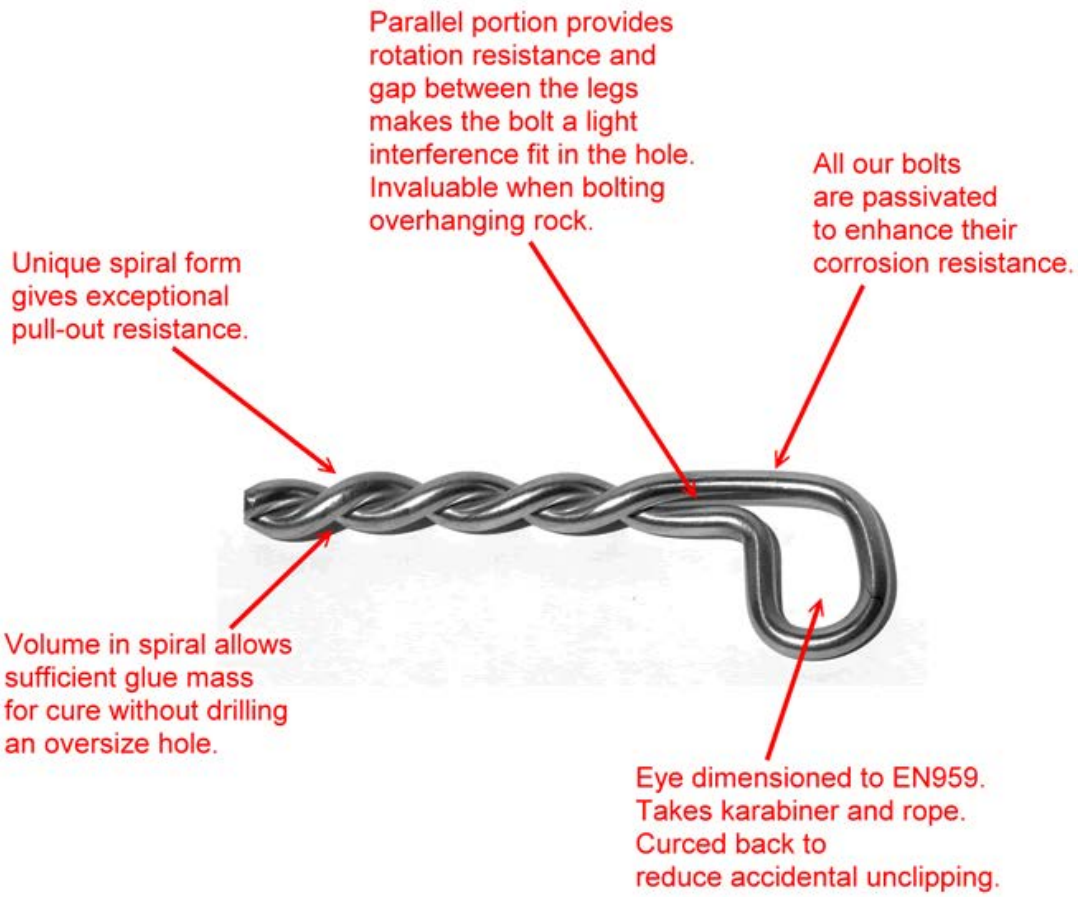
Solid leg glue in bolts

Climbing-specific glue-in bolts generally have an eye at the top so they don't require a hanger. These are nice because you can thread it with a static rope eliminating the need for quicklinks. The single rod, or solid leg bolt, has grooves or notches on the shaft for the glue to have something to grab. This is critical as epoxy glue doesn't adhere to stainless steel very well, but stainless is critical for longevity. Solid legs are either welded or forged. Welds aren't ideal, especially where SCC (stress corrosion cracking) is a concern, but they are not always consistent. In BoltBusters, we have found Fixe's welded glue ins are consistent but the Crux Monster bolts have not been consistent... all super good enough, but still all over the chart.

"P" shape or Continuous Rod glue in bolts

Another option is a continuous rod that is like a U shape bolt, except it is "P" shaped, so it shares one hole like the everlasting titanium Titan Eterna bolts, the bomber Twisted Leg Bolts, and the popular wave bolt. Some of these bolts require a hammer which is unusual for a glue in. The wave bolt requires a lot of hammering as it fits tight like a compression bolt, and Titan's Eterna and Bolt-Product's Twisted leg bolts requires a little bit of hammering because the neck gets tight. The reason for this is so the bolts don't fall out before the glue hardens when installed by climbers in vertical or overhanging rock. The titanium bolts will

last longer than you will because they are significantly more corrosion resistant than 316SS or even the fancy Duplex Steel, though those are also fine in normal conditions. We are fortunate to have them available as a glue in option, as titanium is still a bit too expensive to manufacture as a mechanical bolt. The 316SS Twisted Leg bolts are crazy strong at 79KN and have been very hard to break in Bolt Busters. The glue holds all these bolts well from either notches in the legs or the bent/twist pattern which snuggles that bolt in the security of all that gooey glue.



Threaded Rod

This is literally a ½" threaded rod glued into a hole. Just like everything, too much is bad. It is also important to use stainless steel (SS) and not cut the end that will be exposed to ensure you have really good threads for you to screw your nuts. Cutting exposed ends also risk leaving iron deposits embedded into your precious SS that can cause corrosion, but that is fine if it is embedded in the bottom of a hole surrounded by glue. Many cut the bottom of their rods at an angle so it helps prevent the risk of twisting the bolt in the cured glue (like if the nut seized on the threads and you were trying to remove it with a lot of pressure). "Why cut it at all?" you ask, so you can buy a 12" rod and cut it in half and have two rods. Threaded rod gives the option of using hangers, removing hangers, or turning hangers so the same bolts can be used for multiple highlines. You can also drill a hole in a hand sized rock, glue a nut in the hole and screw the rock onto the threaded rod to hide bolts in sensitive areas. The risk with threaded rod is that the threads can get damaged, especially if removing hangers is frequent and then you are left with a useless stubby sticking out of the rock. These don't save you any money as you need to buy a SS nut, washer and hanger to match the metal you are using. These also have been used to glue death flakes to the cliff that you can't seem to remove. Fully bury the threaded rod and throw a little sand over the exposed glue spot and you have a bomber-ish flake.

Chapter 2 - Glue In Bolt Buying Guide

BoltProducts

- Solid legs come in 8mm, 10mm, and 12mm. The large 12mm bolts have a thick rod which means better bend radius for ropes. Popular among highliners who use threaded rope for anchors. Size of bolt is size of hole required. Comes in 304SS and 316SS. Bolt buster break tests have these welds breaking all over the board but plenty strong enough and I recommend them.

- Twisted leg series is a continuous rod twisted to give the glue a shape to hold onto and allow more glue in the crevices. The 6mm rod (12mm or ½" hole) has a very similar feel to a wave bolt. The 8mm rod requires a 16mm or ⅝" hole and is very very hard to break in bolt busters. These also come in 304SS and 316SS. There is also a large eye 8mm version.

    - The USA distributor is Team Tough but has a limited selection. If you contact them, they can get anything you need.
    - General thoughts: Jim Titt makes great bolts. His website was probably made in the 90s and rarely updated but a lot of the bolting bible came from the information found on his website. They are based out of Germany. Jim is very active in the bolting community.

[Titan Eterna]

- Martin Roberts is an expert on Titanium and made the first certified climbing specific bolts. The continuous rod has no welds and is ideal for corrosive environments like near the ocean. They are more expensive than stainless naturally but not if you consider these could last 200 years. They did great in our Bolt Buster tests. He also sells Titanium U bolts and other titanium quicklinks/rings for anchors. Titan is based out of the UK and [Rap Bolting] is their US distributor. Martin has been very helpful in this Bolting Bible project.

[Wave Bolt](#)

- These win the popular award, are plenty strong enough but I'm not that fond of them. They require a special tool to hammer in and spin as you hammer them so you have to hit them sideways after they are in the hole nice and tight. The tool isn't just to keep a carbon steel hammer from leaving iron deposits on your stainless bolt, but it puts the pressure of your smacking on the bottom of the eye which is stronger than hammering the top in. We have bent these installing them during our Bolt Buster tests. Drill your hole bigger than they recommend and they might be a good option. I don't recommend running a rope through them as the bend radius isn't very large, reducing the strength in your rope. They broke all of our soft shackles before the rope broke! Some people think the tight fit means they are bomber and the glue is just added strength. We pulled them out with no glue at 1.5kn to 2kn in tension (straight out) and in tension was 19kn to 27kn to pull it out. Pretty impressive but make sure the glue is doing the work since we can get 40kn-ish with Ac100 glue and have yet to successfully break them with epoxy.

- Also sold by [ClimbTech](#) and [Rap Bolting](#)

FIXEhardware

[Fixe Hardware]

- Fixe manufactures a ton of options out of Spain and sells in the US. All their high quality products seem to be made with the PLX/Duplex/HCR steel rather than 316SS. They had a glue in with no name that we keep calling “bell shaped” with an MBS of 35kn that gave us great results in Bolt Busters (45kn to 63kn in tension). It has a weld but is buried under the glue when we notch it. Bend radius of the metal is awesome for highline anchor ropes to be threaded through. As of writing this, they only have the 10mm bolt that goes in a 12mm hole. They used to have a super duper long one but I don’t think they sell it anymore. In fact, they don’t sell any long glue in bolts which really crappy rocks need to have.

  - Their newest latest and greatest glue in is their Hely PLX glue in with a wizard’s cane shape for the glue to grab and are forged instead of welded. These only require a 10mm hole but can also have a rope threaded through them. The eye snapped off of the shaft in Bolt Busters right at MBS of 28kn. These seem like great bolts but I hope they keep making the other ones!
  - The company had a recall on their PLX products (see metal section) but fixed the issues. They do make great bolts, one of the few retailers than sells Powers sleeve bolts, and has our favorite PLX hangers. They do sell Plated Steel products without specifying they are for interior use only. They also run out of stock often and have inconsistencies on their website. Overall I like what they make including their glue ins.

Petzl

- These things will break your bank. Their suggested glue cartridges are the worse glue you can use with the most expensive bolts… ironic. They are rated for oddly low numbers but I think they are being very conserative. At least you get 316SS but for these prices of $16 and $27 each, but it should be Duplex Titanium for that price (that's a metal joke!)
- Bat'inox is their big boy at 14mm requiring a 16mm hole
- Collinox is their tiny guy at 10mm requiring a 12mm hole.
- Here is a terrible break test video at 31.7kn (with ampule capsule). It came out of the glue. I think we will test these in epoxy for some real fun!

Threaded Rod

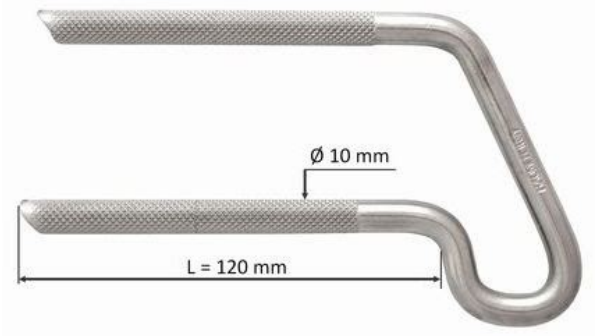
- 316SS, ½" rod for a 14mm hole ideally (5/8" works too but uses more glue) and cut to 5" - Costs $8.10 for 10" which you can cut in half and the SS nut and washer are $1 each on the same site. So $6 plus a $3.35 hanger from Fixe because SS needs to be compatible.
- ***Don't buy home depot unrated rods. Buy rated threaded rods that are the correct length, or double length and no longer, so you can keep the factory finished end exposed and put the cut end in the hole with the glue. The cutting wheel will embed particles into the metal that can form rust otherwise.

Vertical Evolution

- Based in Italy, Vertical Evolution carries 3 different glue in designs named “arrows”, “glue in arrows” and “glue in rings”. You have to ask them for a price list and wait a couple days for it… not your average website where you can just order something and checkout. They have a lot of via ferrata products and variations of the bolts on this page for different anchor setups. All prices below are from the retail price list they emailed me without VAT or shipping.
- “Arrows” are the continuous P shape rods that come in 10mm, 12mm and 14mm sizes. It says stainless but all their other products says 316L but the price sheet I gave specifically says 316L for these. The SS version ranges from €7.90 to €15.20 retail.
- “Glue in Arrow” are welded versions of petzls solid leg bolts and come in 316SS 8mm, 10mm and 12mm. The 8mm and 10mm are available in a bent version and I’m not sure why? These range from €4.60 - €8.40
- “Glue in Ring” is their solid leg P shape bolt but is welded backwards to Bolt-Product’s weld so I’m very curious to test these in Bolt Busters. Comes in 8mm, 10mm, and 12mm and range from €3.60-€6.50
- Their open rope glue in is for anchors, see the climbing anchor page for more about that.
- They also have “Arrow” and “New Arrow” Titanium glue ins that come in 10mm and 12mm and 14mm (up to 150mm long!). I don’t know why the New arrow has that fancy shape but they range from €13.80 to €27.60!

[Raumer]

- Raumer is also based in Italy and has a huge inventory of items. They wholesale from this site and so purchasing bolts can be a challenge. They do have a Retail price list and I think you can order via email or phone. If you go through their "distributor" list, you will find that half the links don't work and most distributors don't carry most of the products. First one I found after a lot of clicking was **Expe**. There are no US or Canadian distributors. However they have unique glue in products and conform to EN959:2018 and UNI11578:2015/A standards. All the products below are 316SS.
- Their Solid leg P shaped bolts are welded "Backwards" like Vertical Evolution's bolts and come in 8mm (Antrax) 10mm (Superstar) and 12mm (Masterfix). 8mm shorties are €4.49 and the longest 12mm is €9.35
- "Radius" is a welded version of petzl batinox but is 10mm
- They have funny looking staples called "Fork" and come in 10mm in 3 different lengths and are from €3.74 to €4.19 each, but the website says it is specific for caving.



[Climbing Technology]

- **Based out of Italy and France, CT carries an 12mm HCR Glue in that is rated for 35kn, goes in a 14mm hole and conforms to EN 959:2007 standards**
- **They also make the same bolt in a 316SS**
- **They also make a larger size in 304SS that goes in a 16mm hole and is rated for 50kn**

The Book of

GLUE

"As soon as it comes out, everything gets sticky."

Chapter 1 - Glues

Glues come in different colors, chemicals, dry times, cure times, lifespans, capsules, tube styles, resistance to extreme temps, and costs. I have rigged highlines, or I should say "tried", where the glue in bolts (that somebody else installed) literally were sitting in a pile of goo because it never mixed right and therefore never hardened. What if someone rigged an anchor that was "partially" cured and therefore looked cured… until they took a whipper and they all came out? This same scenario has happened many times to climbers causing some to be hesitant to make these the new standard. So let's all take a minute to understand the chemistry involved in making the best bond possible.

Colors

The colors are just a manufactures choice more than anything. I love the wonderful qualities of the Hilti 500 V3, but it is red, very red, and that's not very nature friendly. However, in UV light over time, it does change to a dull brown. Other glues come in a grey and brown and everything in between. This could be a deciding factor in what glue you use.

Chemicals

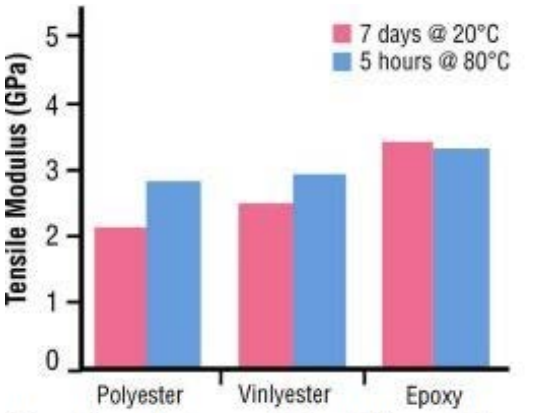
The chemicals that make "rock hard" glue are a resin and hardener. Resin bases fall into one of the following categories: epoxy, epoxy-acrylate, vinylester, and polyester. Epoxies have 4x the bond as polyester, are stronger, are not porous like polyester and therefore last decades longer. The epoxies do take a little longer to cure but like cement, it cures harder if it dries slowly. Epoxies tend to be a bit more runny which can be a negative if the rock is overhanging. Polyesters don't last as long and are weaker, but they cure really quickly and are cheap. Polyester is too weak and has too short of a life span to be used as "permanent" anchor that holds your life and others. Vinylester (like AC-100) and epoxy-acrylate is a middle ground between strength, cure temps and times, and costs. It feels more like grout than liquid plastic so in steep rock it won't drip out of the hole. It is super good enough for many bolts but not as good as epoxy.

Dry times

Dry times or gel times are the amount of time you can spend installing the bolt before you risk damaging the bond. If you yank on a bolt that is half cured, you could damage that bond significantly. An epoxy that takes 6 hours to cure, lets you play with it for around 30 minutes, but a vinylester that takes 20 minutes to cure gives you about a minute or two to get that bolt in.

Cure times

It's important to know your cure times because it matters! Don't use bolts that "look" cured. Follow the specs so you don't die. This is very temperature based. The colder it is, the longer it takes.



Cure time & strength in different temps

***Epoxy is much stronger after fully curing**

Wet Holes

So many jokes here but I'll hold back. It is OK if the hole is wet when you install your glue, but typically takes twice as long to cure

Lifespans

Lifespans or shelf life all depend on how they were stored and can vary as short as 9 months like Liquid Roc 300 (a polyester) to 18 months, or even as long as 24 months like most epoxies. We have used expired glue Hilti 500 v3 in Bolt Buster and had great results, it tends to just cure slower, but its not exactly cool to be using glue outside of manufactures specs on bolts people will be depending their lives on.

Capsules

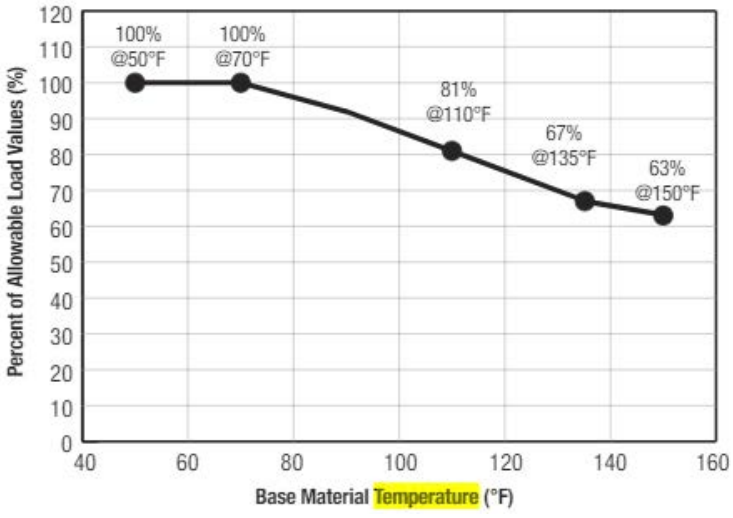
These look like big pills that you would stick up your ass, but if you want to shit again, I wouldn't do that. They are a more convenient method as you "just" put the capsule in the bolt hole and hammer in your bolt, BUT you can do this wrong a lot easier than when using a tube style. They come in both hammer and screw styles, and it is important to read the installation section below before using them!

Tube styles

Tube style or cartridge style are either a single tube that fits most standard caulk guns (check this first as a trip was ruined because the plunger didn't fit!) or a double tube that requires a very special dispenser tool. Some come battery powered if you like it fancy.

Temperatures

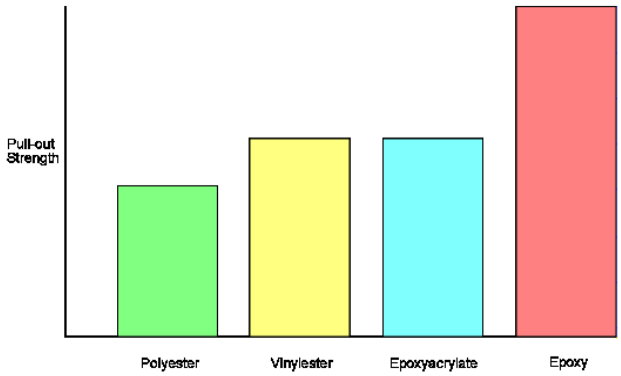
Curing really depends on temperature. For example: some epoxies like Simpson XP require a minimum of 50F (10C) for 3 days which can be unrealistic in the mountains but others can cure as low as 14F (-10C) in half a day.



And, did you know some glues can even lose strength AFTER they are cured if exposed to really extreme high temps? If an area gets too hot like the desert, it can drastically reduce the strength of some glues. In fact, a heat gun is (in theory) one trick to removing glue ins. However, is 75% of the strength of a quality epoxy really a concern since it is so overkill? And do you plan on taking whippers when it is 110F? Wildfires have been known to compromise the glue on entire crags. Working times are also sensitive. If installing on a hot day, keep your cartridges out of the sun! It can limit the working time or make it too runny. Too cold is a thing also, we took liquid rock 500 to the desert in winter to do tons of testing and we couldn't get the glue out of the tubes! At 32F (0C) it was practically frozen inside, but our backup Hilti glue worked great. Know your area, and know your glue.

Strength

Epoxy cures slower, but that is one reason it is stronger… a lot stronger than polyester. Vinylester and Epoxy-acrylate is in between but epoxy always stands above them all.



Adhesion

Nothing sticks well to stainless or titanium. All of our BoltBuster tests where the bolt was pulled out instead of breaking, there was no glue left on the metal. That is why all the glue in bolts have twists or notches or threads where the glue will surround it so it has a physical mechanical grip on the bolt itself. Sometimes roughing up the metal helps the glue to adhere but shape is way more important.

Costs

Money is often a factor for the bolter. To spend almost $60 on just glue and buy special dispensers for $163 like Hilti's setup, could make an installer cry, but then again, this could be an anchor that could last for 100 years if done right. Or you can buy some stainless wedge bolts for around a buck each plus a hanger for about $2 and that doesn't require much more than the drill. **However, if money is a deal breaker for you… should you really be installing anchors that hundreds of people will risk their lives on?** Get your dispensers used on ebay, ask your buddies that will enjoy the route or highline to help chip in $20 each, and you can have something you are proud of when you are done.

Chapter 2 - Glue Buying Guide

Quick Tip: If you want the best Hilti 500 V3 is a high quality epoxy that isn't temperature sensitive and naturally isn't cheap. If you want a super good enough vinylester that is a user friendly and cost effective product, then AC100+ Gold is your answer.

- ***Hilti 500 V3***

  - Epoxy… Color: Red
  - technical info
  - 2 year shelf life
  - Available only in 11.1oz dual cylinder at $50.00ish each
  - Special dispenser required: Manual or Battery (check ebay for deals first!)
  - Installable at 23F to 110F (-5C to 43C) with a lot of working time
  - Cures at 23F (-5C) in 7 days
  - Cures at 72F (22C) in 6.5 hours
  - Cures at 105F (41C) in 4 hours
  - Opinion: This is the best stuff you can buy. It cures fairly quick for being an epoxy and can handle the extreme temperatures. It is very red and one of the more expensive options though.

- ***Hilti-RE 100***

  - Epoxy… Color: Purple
  - technical info
  - 2 year shelf life
  - Available in 11.2oz dual cylinder at $19.25 each (and 16.9oz and 47.3oz)
  - Special dispenser required Manual, or Battery
  - Installable at 41F to 104F (5C to 40C)
  - Cures at 41F (5C) in 3 days
  - Cures at 68F (20C) in 24 hours
  - Cures at 104F (40C) in 4 hours
  - Opinion: This is the cheaper epoxy that Hilti sells. Its range of temps is worse, takes much longer to cure and is about half as strong as 500 V3, but it is still a solid epoxy. There are better epoxies in this price range.

- ***Hilti HIT-ICE***
  - Epoxy… Color: Unknown
  - 10.14oz costs $66.99
  - technical info
  - Installable at -10F to 110F (-23C to 43C)
  - It is 64% of its strength at 155F
  - Cures at -10F (-23C) in 3 days
  - Cures at 40F (4C) in 1.5 hours
  - Cures at 70F (21C) in 45 minutes
  - Gel time is only 5 minutes at 60F and 1 minute at 90F
  - ½" threaded rod in a ⅝" hole at 4.5" embedment at 4000psi
    - =5,780lbf tension
    - =12,445lbf sheer
  - Opinion: You won't bleed from the price because you would only use this in places your blood would freeze before coming out. This is an expensive option for <u>really</u> cold applications. Half as strong as Hilti's V3 500 but still plenty strong for being the only glue in this guide that goes -10F.

- ***Simpson SET-XP***
  - Epoxy… Color: Grey/teal
  - 8.5oz costs $24.98 or $23.69
  - technical info
  - Normal caulk gun dispenser for 8.5oz or a Special dispenser required for the 22oz and the 56oz versions
  - Installable at 70F to 110F (21C to 43C)
  - It is 67% of its strength at 135F
  - 2 year shelf life
  - Working time is quite a while
  - Hole can be submerged in water
  - Cures at 50F (10C) in 3 days
  - Cures at 70F (21C) in 24 hours
  - Opinion: This is good ol' epoxy. It cures really slowly and the temperature range is lame. It's going to last a long time but you need to put it in days before you need it, and in garden of eden like conditions.

- ***Simpson AT-XP***
  - Acrylic…. Color: Grey/teal
  - 9.4oz costs $15.92
  - Technical PDF
  - Special dispenser required for the 30oz but not for the 9.4oz
  - Installable at 0F to 100F (-18C to 38C)
  - It is 76% of its strength at 150F
  - Cures at 0F (-18C) in 24 hours Cold temp install notes
  - Cures at 68F (20C) in 1 hours (gels up in 4 min!)
  - Water saturated applications require double the cure time
  - Opinion: Simpson's version of acrylic. A lower temperature, quick drying glue that is a step above polyester and a step down from epoxy. Hitli's Ice does colder temps but costs 4x more.

- ***Dewalt AC100+ Gold***
  - Vinylester… Color: Gray
  - Product page
  - 10oz costs $15.00 to $20.00
  - Available in 10oz single tube and 28oz dual cartridge
  - Installable at 14F to 104F (-10C to 40C)
  - It maintains 85% strength at 105F (41C)
  - 18 month shelf life
  - Use to be Powers, now it is dewalt
  - Cures at 14F (-10C) in 24 hours
  - Cures at 68F (20C) in 45 min
  - Cures at 104F (40C) in 15 min
  - Opinion: This seems to be the go-to glue for climbers probably because it cures in 15 minutes, anti-drip friendly and is a good price. Better move fast because your working time is only a minute or two. You may not die using this but the epoxy is going to give better, long term results. It can be very sensitive to shelf life and storage temps. However, this wins the "bang for your buck" award. This is cold friendly and people bolt when it is too cold to climb.

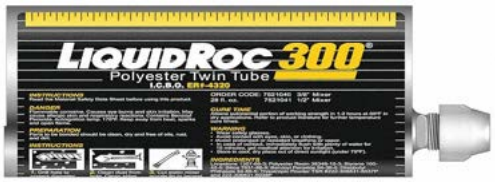
- ***Liquid Roc 700***

  - Acrylic
  - Color: gray
  - Download tech sheet from product page
  - 18 month shelf life
  - 10oz costs $32 ish and also comes in 28oz
  - Cures at 14F (-10C) in 15 hours
  - Cures at 59F (15C) in 1 hour
  - Cures at 86F (30C) in 20 minutes
  - ½" rod in 9/16" hole at 4.5" embedment at 4000psi concrete has a WLL of
    - 5,439lbf Tension
    - 4,674lbf Shear
  - Opinion: This is the best performing glue for really cold conditions. A bit pricey but is strong and drys fast. If I was installing glue ins in 14F, I would just use Powers AC100+ Gold. If you need glue for even colder, Hilti Ice is your glue.

- ***Liquid Roc 500***

  - Amine base epoxy
  - Color: Gray
  - Download tech sheet from product page
  - 24 month shelf life
  - Long term loading
  - 8.5oz costs $19.86
  - Cures at 80F (26C) in 6 hours
  - Cures at 60F (15C) in 24 hours
  - Don't use below 40F (4C) - like seriously. I was fucked in moab when doing our sandstone tests. It doesn't come out of the nozzle.
  - ⅜" rod in a ½" hole at 4.5" embedment at 4000psi concrete
    - =9,540lbf tension
    - =5,810lbf sheer
  - Opinion: A comparable epoxy to Hilti 500 V3 when it is nice outside. This won't cure below 40F but it is less than half the price. It is also 20% cheaper than Set XP and drys twice as fast as it. It also fits a standard single cartridge dispenser. SUCKS WHEN IT IS COLD OUT!!!!

- ***Liquid Roc 300***



  - It is a Polyester resin base
  - 9 month shelf life
  - **Short term** loading
  - 28oz double cartridge at $25ish (no single tubes)
  - Cures at 80F in 30min
  - Cures at 60F in 1 hour
  - Cures at 28F in 4 hours
  - Opinion: **Don't be a cheap ass… don't use polyester!**

- ***GEBOFIX EPO PLUS RE***

  - Sold by Raumer and Titan Climbing for about €22
  - Tech Specs
  - Gray color
  - Titan says comparable to Hilti 500 v3, not in working temps and times but maybe in end result. It is actually more like Simpson Set XP
  - Storage 24 months
  - Storage temps 5C to 35C
  - Working time at 50F or 10C is 2 hours
  - Working time at 104F or 40C is 5 minutes
  - Cures at 50F or 10C in 3 days
  - Cures at 104F or 40C in 4 hours
  - Requires special dispenser, also available on websites

- ***Bolt-Products Epoxy Acrylate***
  - Epoxy Acrylate
  - ZERO SPECS AVAILABLE ON WEBSITE
  - 400ml (13.5oz) costs €15,60
  - Dispenser available on website
  - Opinion: Website says it is a healthy balance between long term and price. But they don't have any specs and you should really know those before installing any type of glue. Bolt Products sells some of the most bomber bolts in the world and doesn't sell epoxy???

- ***GEBO Super Hybrid***
  - Sold by Raumer for about €12
  - Tech Specs
  - I don't think it is an epoxy but they throw the word "Certified" around a lot
  - This is a "healthy" version of glue but I still don't recommend you eat it.
  - Storage 18 months
  - At -5C or 23F - 20min working time and 12 hour cure time
  - At 35C or 95F - 3 min working time and 20 minute cure time
  - Based on the temps and times, it sounds like a european version of Ac100, their Retail list calls in a vinylester.

Capsules: Without testing the screw in style, I CANNOT recommend any of them. Those should not be "hand twisted" but rather attached to a hammer and rotated... a lot! Raumer has an adapter that you can mechanically twist the bolt. The Powers Hammer Capsule specs seem impressive (dries fast, is strong and is cheap) though your bolt options are limited. Most options here are the substandard polyester glue that shouldn't be used.

- ***Liquid Roc 300 Hammer Capsule***
  - For short term loading only
  - 10 Pack costs $30ish (be sure to check the size you need first)
  - Cure in 10min at 68F
  - Cures in 1 hour at 32F
  - 23F is as low as you can go
  - Only use square cut end on threaded rod
  - Opinion: The numbers sound good, the cure time is appealing, but this is polyester and so it isn't as good as epoxy. Also, not all glue in bolts have a blunt end so they wouldn't be able to be used on this. I DON'T RECOMMEND.

- ***Liquid Roc 300 Capsule*** *(spin install)*
  - For short term loading only
  - 10 pack costs $30ish (be sure to check the size you need first)
  - Cure in 10min at 68F
  - Cures in 1 hour at 32F

- 23F is as low as you can go
- Pointed rod is critical
- Specs require mechanical spinning
- Opinion: This is the same thing as above, but the spin part of the install cannot be properly achieved without attaching the bolt to the drill and spinning it. I DON'T RECOMMEND.

- ***Petzl Capsules***

  - Ampoule Bat'Inox for 14mm Petzl Bat'Inox
  - Ampoule Collinox for 10mm Petzl Collinox
  - Polyester resin base
  - 3 year guarantee
  - Break tip with hammer, "twist bolt in 10x minimum"
  - Costs about $5 each, at that price you could install epoxy
  - Cures at 20C in 40min
  - Cures at 10C in 1 hour
  - Cures at -5C in 10 hours
  - UIAA rated for 15kn tension and 25kn sheer
  - Opinion: I don't believe hand twisting these is sufficient so I cannot recommend them. It is also a substandard glue compared to epoxy. **Why would you put in the most expensive glue in bolt into the cheapest glue, WHY Petzl???**

- ***Powers Hammer Capsule***

  - Epoxy Acrylate Resin
  - Costs almost $30 or box of 10
  - Shelf life 2years
  - Hole can be damp but no standing water or frost
  - Cures at 68F in 1hour
  - Cures at 50F in 2hour
  - Cures at 32F in 5hours
  - ½" diameter 4 ¼" embedment in 4,000 PSI concrete
    - = 10,240lbf Tension
    - = 10,720lbf Shear
  - Opinion: If you are going to use a capsule, this seems to be a good one. Doesn't require mechanical spinning, it is a form of epoxy, dries quick enough and is a good price.

INSTALLING GLUE IN'S

"If the hole isn't clean, it can be really risky!"

If you have the right bolt and the right glue and the right stoke, you can still screw (or glue, get it?), this up and kill someone. You don't have to be a nuclear physicist to install a glue in bolt, but you DO have to do the simple instructions or you can kill someone. Let's emphasize the killing someone real quick. **<u>This isn't about long term vs short term anchors here. We are talking about them coming out, AKA killing someone if they don't get put in correctly.</u>**

Another way to fail, that has less consequence, is by failing to actually install the bolts you set out to do. You spent weeks reading the Bolting Bible, spent a bunch of money, used a good weather weekend, and you get there and find out the plunger is too big on your dispenser to push out the glue. Or that cheap caulk guns are too weak to push cold glue out. You could run out of battery before you finish drilling, or find out you left the extension tips to your mixing tips at home... so now you can't put the glue in the back of the hole, *after* you cut open your tube! Nope, none of these have ever happened to me… nope… not me! Taking preparation and installation seriously can make you a bad-ass, otherwise you might just be a dumb-ass!

Chapter 1 - TOOL LIST

- Bolts, duh! The softer the rock, the longer you want your bolt.
- Glue cartridge + Dispenser ...OR Capsules
    - Spare mixing tips and extension tips
    - NOTE: 10oz fills around 10 holes roughly but if you have to change out mixing tips often, you lose quite a bit each time you change one.
- Knife
- Drill, and correct size bit, plus spare bits
- Safety goggles
- Face mask - rock dust isn't good for you.
- Ear plugs if drilling a lot
- Pipe cleaner and blow pump (for really clean holes!)
- Rubber gloves and paper towels! It can get messy.
- Tape for a perimeter around notch so it doesn't ooze everywhere AND you can tape mid way up your drill bit so you know how far to drill
- Cotton swabs for detailing in case it oozes out a lot
- Bag for garbage
- Bag for testing mixture (see "Filling Hole" below)
- Plastic or covered Hammer (For bolts with a tight fit)
- Wave installation tool (for wave only)
- Heart full of stoke and a car full of friends!
- Bag to go on your harness for installs in the vertical world

Chapter 2 - TRAINING and PREPARATION

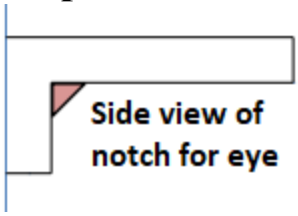
Please please don't let your first glue in bolt be anywhere important. Do several in your backyard or your parents backyard or the backyard of someone you don't like when they are out of town (kidding! Just kidding! Jeez). If you think that would be an eyesore, now you know how all the rock huggers feel that complain about over-bolting. You can read this Glue In Section 100x, but you will **always** have kinks to work out, and kinky stuff should be done at home. Practice also helps you verify you have the right drill type, bit type, bit size, glue accessories, amount of glue, cleaning tools AND TECHNIQUE. Or... you can just wing it and go learn in a popular area, but just make sure you put your name on it so we know who to troll!

Can you answer the following questions about what is in your bolt kit bag?

1. What are the min and max cure temperatures?
    a. What temperature will it be when I install these?
    b. Can the glue even be installed at the installation temperature?
2. What is the nozzle time? (how long can it sit in nozzle before you have to put a new one on)
    a. Do I have spare nozzles
    b. Do I have spare extension tips to get the glue in the back of the hole?
3. What is the working time so I don't ruin the bond before it is cured?
4. Will this glue run out of a hole if I put it in horizontal or in an overhanging rock?
5. What is the cure time for low, medium and high temps?
    a. When do I plan on climbing or highlining on these bolts?
6. Did I charge my batteries for my drill? Do I have spare batteries?
7. How deep do I need to drill, and will I need a notch?

8. Do I have a way to keep things clean and tidy?
9. How many holes can I fill up with one tube?
10. Do I have the right bolt for my glue capsule (angled end for screw install and blunt end for hammer install!)
11. How am I going to put warnings on my bolt if it requires several hours to cure so no one uses them after I leave?
12. Does the fluid move in my glue capsules?
13. How long has my glue cartridge sat on my shelf?
14. Do I have the proper pipe cleaner and blower to get a really clean hole?

Chapter 3 - DRILL HOLE

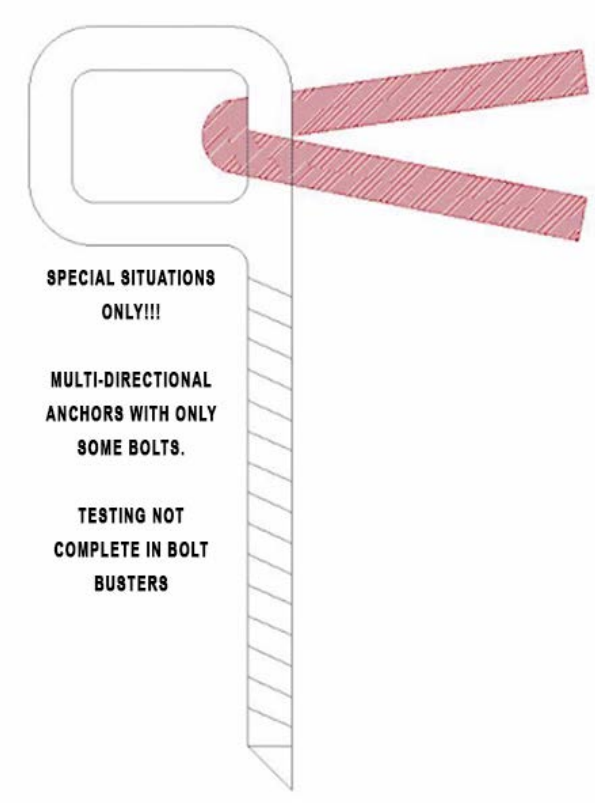


All glue in bolts have an intended hole size. Solid leg bolts are going to slip right in and P shape bolts have to be pounded in. Wave bolts act like a piton and take a lot of pounding and the Titan bolt takes a mild tap as the neck gets tight at the top. If these holes were drilled too big, it wouldn't be the end of the world, you just lose a nice feature that they have of not falling out and you would be wasting glue.

Some glue ins require a notch so the bolt is inset a bit. To make a notch for a bolt you have 3 options. Drill a ½" deep hole about an inch or so away from hole and then tilt the drill bit 45 degrees towards the main hole. OR stick the drill bit inside the main hole and tilt it a lot and drill away from the hole. OR drill 3 straight down holes, ½" deep, next to your main hole

CAUTION: If the notch is too deep, you lose a lot of space in your eye, limiting what can be clipped to it. And if it is excessively deep, it could force the rope to sit on the rock creating abrasion. PLEASE: Make sure the direction the bolt is facing is the direction of the force. It is pretty easy to guess in climbing situations… straight down! But if you are building a highline 3 point anchor 2 feet from a cliff edge, what angle will those outside bolts be???

SPECIAL SITUATIONS:

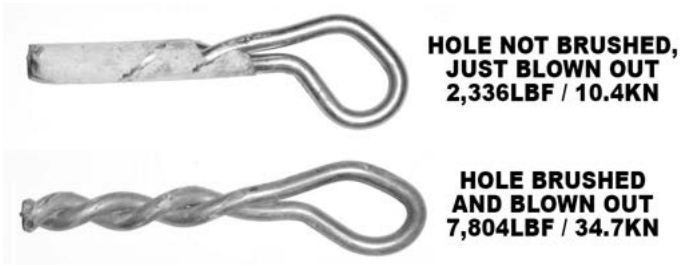


If there is any chance this bolt will need to be pulled in more than one direction, ie: multiple highline variations or spacenets, then use a "P" shape bolt and drill the notch so the bolt will be installed BACKWARDS so the anchor rope will be pulling on the spine. This allows it to be pulled in 170 degree without the risk of twisting the bolt and compromising the glue. Bolts in general start to deform before breaking, even more so when pulling on backwards. 8mm twist bolts we tested changed shape around 10kn even though the final breaking strength was 40 or 50kn. However, if pulling sideways on them installed "normal", it started to deform around 4kn but also had very high final breaking strengths. These tests showed us the bolts bent before twisting the bolt out of the glue. We have also found in BoltBusters that the weld on Bolt-Products straight leg series gives us wildly different results and for backward Ps, it leverages that part of the bolt that was weakened by the weld. In our backward tests, they started to bend around 20kn and broke anywhere between 21kn and 45kn after that. Installing backwards Ps are for very specific goals and they should be installed forward like recommended in almost all scenarios. This is just one solution to a unique scenario.

Contrary to what you would think, don't drill an angled hole away from the projected force. That lever action doesn't make the bolt stronger but puts all the force on the rock at the top. See the Book of Holes about the research done on this.

If you are using capsules, then depth AND diameter are very important to get right since you can't just add glue if you don't have enough and no one wants to clip a glue in bolt when they can't see the damn glue! This is a great reason to test it at home, and if you don't want a bolt in your backyard, pull it out before it cures. But this way, you know you got the right system at the cost of only 1 or 2 capsules. (A trick to get your depth perfect is to put several layers of duct tape mid way up on the drill bit where you want it to stop.)

Chapter 4 - CLEAN HOLE



This is a huge fear when an experienced bolter hears a new bolter is stoked to go install glue ins. If the holes aren't cleaned really really well, someone could very likely die.

Really clean it! That requires a pipe cleaner AND a blow tool. A blow tube and your lungs aren't enough, even if you are really good at blowing so get a dust blower like this pump, or Hilti's pump . A can of air also can do 20 to 30 holes and is light. A Battery Powered blower compatible with your drill battery can also be a gamer changer. A wire brush tube/pipe cleaner can be bought from anywhere. Regardless of how rough or porous the rock is, drilling a hole polishes the sides of the hole, so in order to get the **glue to bond with the rock** (which in case you don't know, that is important, and if you don't know that, please don't put any of these in), the rock can't have any dust film on the sides. Do a fun experiment at home, put super fine construction dust on your granite countertops at home, then try blowing them clean… blow hard… even with an air compressor you can't get it truly clean. Same with the wire brush, you can't JUST use the brush. Blow then brush, again and again and again until it is super clean. Always start with the blow.

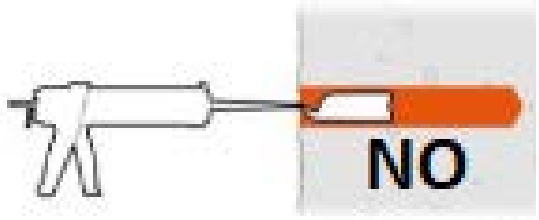
Chapter 5 - TEST AND CHECK

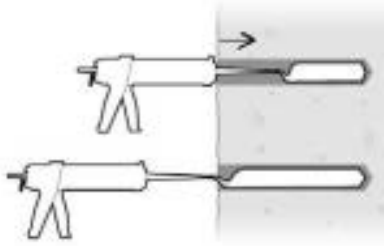
Dry fit the bolts, if possible, to make sure it will work. If you are putting a wave bolt into a ½" hole then you can't do this but you can verify with a stick or the tube cleaner that the depth is perfect (too deep is better than too shallow). The biggest crux is to make sure your notch isn't too deep or restricting the bolt from being the angle you want. Get all your stuff laid out and ready, cus when you start gluing, the working time clock is ticking. Know your working time, because if you are using Powers AC100+, and it is hot out, AND it takes you more than 1 minute to get to the next bolt, or even spend more than 30 seconds hammering in a wave bolt… you will need a lot of mixing nozzles and therefore won't be able to fill as many holes as you think with each tube of glue. For climbing, drill and clean on your way up a route, then glue and install on your way down the rope as this will have shorter transition times.

Chapter 6 - INSERT GLUE

CARTRIDGE: If you're 100% ready to start, cut your glue cartridge open, squeeze just a bit without the nozzle to see that both colors are coming out, then install the mixing nozzle. But… before you start shoving your tip inside of holes, make sure what's "coming" out is safe! You can't just put the first squeeze into the hole. This is one the main reasons you will want paper towels. Squeeze a COUPLE times to make sure it is **mixed properly**, which you can generally tell by the color. THEN grab a ziplock bag and squeeze a quarter size amount into the corner. Only after all that… start putting it in the hole. This ziplock bag is so you can check later to make sure your first squeeze of glue hardened.

Jim Titt from Bolt-products.com said in a Mountain Project thread "over a period of 7 years the DAV recorded 17 failed resin bolts… one climber died." VERY IMPORTANT… Start in the back of the hole and work your way out. Don't fill it up to the very top because the bolt will push out the amount of space it replaces. Somewhere around ¾ full is good. When you are done, squeeze some into the other corner of the bag and take it home as a souvenir… also to check your first and last squeeze to make sure both get rock hard. If they don't, it didn't mix right! Battery powered dispensers can help mix the glue more evenly and just be easier than a manual dispenser but they definitely cost more.





How much glue do you need? You can get almost 20 bolts out of a 10oz AC glue cartridge if they are ⅜" (10mm) and short. I was barely able to do 8 when I used Hilti 500 v3 glue on long Crux Monsters.

HAMMER CAPSULES: Spin the capsule around a couple times to make sure all the resin is in liquid form because if it isn't it won't mix correctly. You are literally shoving harder around it so it has to be liquid. Insert with the hardener facing up. If you think of it like a cigarette, then what looks like the filter, is closest to the top of the hole. That is the hardener and if it isn't at the top you aren't going to be mixing anything. The capsules are glass and you are smashing a bolt through it, so wear safety goggles. Your bolt has to have a flat/blunt end. A tapered end won't push the hardener down into the resin. Make sure you have the right size capsule because if it is a ½" capsule in a ⅝" hole, then it will be leaning to one side not mixing things evenly, and you probably won't have enough glue to fill up your hole!

SPIN INSTALL CAPSULES: Spin the capsule around a couple times to make sure all the resin is in liquid form because it if isn't, it won't mix correctly. These spin installs have a glass container inside of another glass container. One

has resin (the amber liquid) and the other has hardener. There are sand chunks in these so it scores sides of the hole and helps mix the glue. These capsules (at least from Petzl) require that they stick out of the hole by 10mm so you can break the glass with the hammer, then insert the bolt. These bolts must be angled on the bottom in order to mix these correctly which is different from the hammer capsules. Now to do this properly, the spinning requires mechanical spinning, and there are special adapters for your drill that you can attach the bolt and spin it. Petzl system is to manually spin the bolts in their instructional videos, but I don't believe that is how they should be used. They say to spin the bolt 10x. That doesn't mean 10 turns with your hand, that means 10 full rotations which is more like 20 times with your hand. If you use this system, spin them like your life depends on them. This system obviously doesn't work for wave bolts because they can't be spun as they fit tightly in the hole.

Chapter 7 - INSERT BOLTS

If using a threaded rod, squirt a bead of glue along the threads before putting it in. For the bolts that don't require hammers to install, like Bolt-Product solid legs, Petzl and Fixe bell shape or PLX, you will want to slowly push them in and TWIST them while you do it. Fixe bolts have a weld, and you want that weld facing away from force, even if it is buried under the glue. You don't want air pockets around notches or threads. If you hear air bubbles gurgling as you push in bolt then you don't have glue in the back of your hole!!! No bolt queefing! Pull out the bolt and make sure it is super full of glue.

If you are using Wave bolts, Titans or Twist bolts, then you need a hammer, but you don't want to hit a stainless steel or titanium bolt with a non stainless or non titanium hammer. Since that would be one expensive, fancy hammer, you can use the wave installation tool that is made from stainless and it puts the force on the right parts of the bolt, or use a rubber mallet, or plastic hammer, or just put a rag between the two

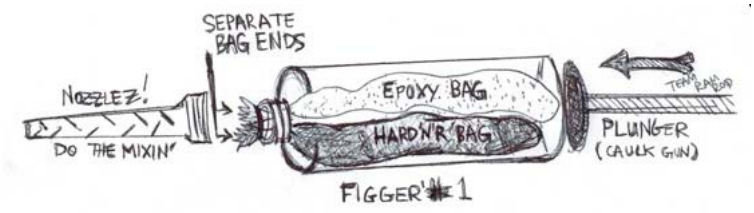
metals. The point is, your hammer will transfer iron onto your fancy expensive bolts and those iron particles will start rusting making your fancy bolt look like it is corroding. This is the same reason you don't want to grind threaded rod to the length you want if the cut end is exposed to the elements. Yes, we clip non-stainless carabiners, shackles and unfortunately most quicklinks, but they are not striking the bolt enough to transfer non-stainless to bolt. Keep in mind, the Wave bolt will twist as you hammer it, requiring you to hit it sideways to orientate it correctly, not sure if that is good for the bolt or the glue but people do it. One option is to drill the hole bigger for the Wave Bolt, you will lose the tight fit, but you don't need that unless you're installing it in an overhang.

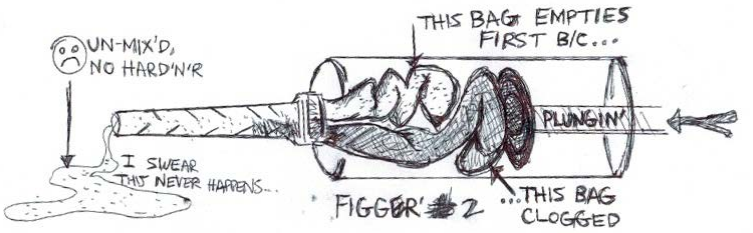
Chapter 8 - FINISHING TOUCHES

If you put a perimeter of tape around a notched hole, then after gluing you can just pull the tape up and it will be a nice rectangle of glue, otherwise you risk it getting everywhere, and if the glue is red, that can look really bad. Cotton swabs are convenient for cosmetically making the glue look nice. Be sure to clean off the glue that got all over the eye of the bolt if it squished up too high. Have a lot of cotton swabs handy and a bag to put them in. Saving some of your rock dust may help because you can possibly hide the glue color by sprinkling the dust on top. No, a little dust ON TOP of your glue won't kill anyone and will make it look nicer. Use dust and not rock crystals on your glue so there is less risk of abrasion on the rope anchor. All this cleaning is a lot easier with rubber gloves. If it is an epoxy that takes many hours or days to dry, label it with a date preferably so people don't use it before it has safely cured.

Chapter 9 - Troubleshooting

1. Why doesn't my glue come out the right color???
    a. Well, that's probably because both parts aren't coming out! Single cartridges may not be evenly dispensing like the image below, or one of your dual cartridges have ruptured like the image with the messy Hilti gun. Get a new cartridge and start over.





2. Ah shucks, I drilled the notch too deep and now the eye is recessed too much, how do I fix it???
    a. Just put a piece of gravel, small pebble or something non dusty in the bottom of the hole or in the notch, if it will stay, to prop up the bolt until it cures into the position it will be forever.
3. I just heard my bolt hole fart. Does it have enough glue?
    a. If air comes out as you put in bolt, it does NOT have sufficient glue!
4. I hammered in my glue in and it won't go all the way in
    a. Wave bolts can feel so tight that it is hard to get them all the way in. I like to lightly wallow out the hole so it isn't so tight.
    b. The other possibility is you didn't drill the hole deep enough. Take bolt out and redo it. It will be a royal mess!
5. My bolt is on a steep rock and keeps slowly sliding out!
    a. Tape it to the rock or worse case wedge a tiny pebble or stick between the rock and the bolt shaft to hold it in place, but be sure your wedge is below the surface of the glue so it doesn't look sketchy later.

CHAPTER 10 - How NOT to Bolt

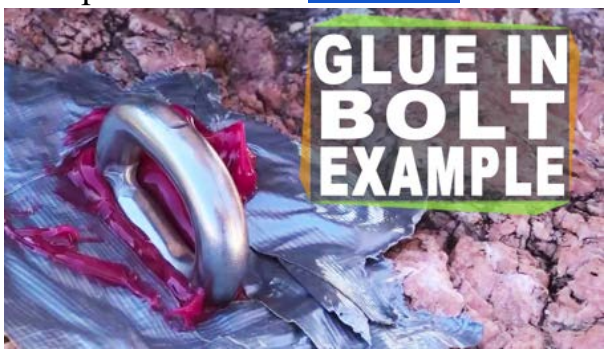
I couldn't believe how many "How to" videos had mistakes in them. Here is a list of instructional videos we found online and some feedback on their technique.

1. This video is actually pretty good. They properly install a spin type capsule. If I am going to overly picky, he doesn't blow his hole out after brushing it and he left too much glue sticking out, so his plate didn't sit flush. What is interesting about this video is that it shows that this is how spin capsules are supposed to be installed, whereas climbers don't do this.
2. This video is another good one, but he doesn't wear safety goggles. And I'm not just getting on a high horse here as I've been hit in the eye before! And it blows dust into his face. I like the fact he uses a proper blow tool. He doesn't bury the eye which is one of the few instructions Fixe does require! I like that he mentions the hammer leaves iron deposits, so he uses a rubber mallet. I don't like the fact this is only manually spun to mix the glue, and I'm not excited he keeps pulling it in and out. Is that glue surrounding the shaft entirely or is he getting air pockets doing that?
3. This video here is a really bad example. He only vacuums out the holes which does almost nothing for the dust on the sides of the hole and doesn't brush them… wow. I also don't think that he spins it enough.
4. This video is the same as number 3, but uses a cartridge instead of capsule. He vacuums his hole again, which is a shame, and he should put a little glue on the threaded rod before inserting it into hole. You don't want any air pockets around your threads.
5. This video is pretty good but doesn't use a wire pipe brush and just hoses out the hole. He also makes a mess which is ok for what he is doing, but not if he did it on rock.
6. This video here is the winner! **HOW NOT TO BOLT!!!** By Hilti themselves! Installs glue in a dirty hole. He seriously

pushes the dust out as he fills the hole with glue!!! The video doesn't explicitly say it is the SafeSet Technology which is the only exception. That Hilti system can be used without cleaning the hole. This requires a special bolt shaped in a special way and made with a materials that won't allow the glue to stick to bolt, so when it trys to come out, the HIT-Z bolt flanges on bottom expand the glue like a wedge bolt does to the clip. These bolts are only zinc plated, and no one uses these for climbing applications. The system also requires the HIT-HY 200 glue and not just any epoxy. This video should specify that it is only for that unique system.

7. This video is by the Access Fund and they did a great video but it has some flaws. He talks about a clean hole, but only cleans it one time. It should be 3x or 4x. He talks about pumping the first squeezes out to make sure the color looks right so the mix is right, but doesn't do it on camera. He talks about not hitting it directly with a hammer, then does it at the end to twist it into position.
8. A GOOD EXAMPLE… OK, I lied, there was one video by Powers that gets a pat on the back. They clean the shit out of the hole and they pre-squeeze a lot of glue out before putting it in the hole. Look at how much dust comes out on their second phase of blowing it out! And look at the color change as they squeeze out the initial glue. Great example!
9. Another Good Example… Climbtech put out a good video in a real life climbing situation. They had fancy tools for hanging situations. They were able to reuse the hole from a bolt they removed, and the wave bolt fit in nicely. It wasn't super tight, but tight enough to hold.
10. Another good example - teamBMC youtube channel had a good video on how to check glue in bolts.
11. Another good example - Derek Bristol has a channel on caving and made a good video about installing glue ins. He also has a good video on Fixe Triplex Removables.

We have 2 glue in bolt installation videos available….
David Keller shows us backwards P (only for specific niche purposes!) in this EPISODE and we install bolts for the GGBY Spacenet in this EPISODE



HOW NOT 2 HIGHLINE

Watch all of our bolt videos on this *PLAYLIST*

Subscribe on Youtube and follow us on Instagram and Facebook.

Juno COFFEE

If you are enjoying this book, please consider ***Donating*** on paypal or support our **Juno Coffee** startup or purchase **T-Shirts**! If all you can do is send positive stoke to our inbox, we love that too!

Lots of stuff on
www.HowNOTtoHighline.com

The New Testament

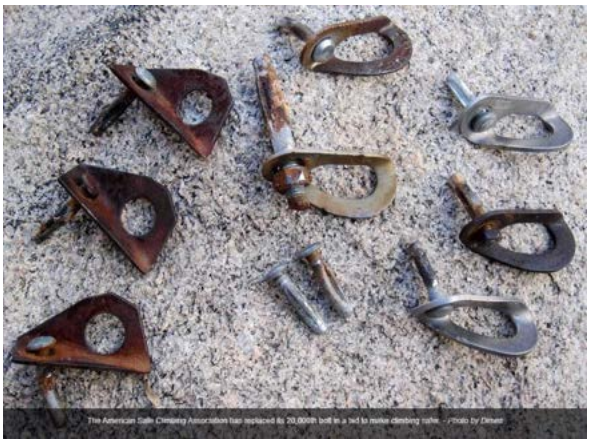
How to remove & replace bolts + Bolt Buster break tests

The Book of

Pulling Out

"Pulling out isn't as much fun than leaving it in there, but sometimes it is safer"

You're about to hit the crux and you get to a bolt that looks more sketch than a 000 cam in wet sandstone on Friday the 13th. Unfortunately, some bolts installed do not pass the test of time and need to be replaced BEFORE they kill someone. It's not ideal to have a bolt pull out while you are in the midst of using it, but when our bolting angels go to replace bolts they can be tricky to remove in such a way that the hole can be reused. This chapter talks about all the different ways to remove old bolts.



Ethics are important when re-bolting. Retro-bolting is when you add bolts to an existing climb. This is frowned upon by most of the climbing community but in some situations this can be done to improve the quality of the climb or make it safer, if the F.A. (first ascensionist) is consulted or if they are unavailable, community consensus is obtained. The goal of rebolting is to reuse every hole so our rocks don't turn into swiss cheese. If quality stainless or titanium bolts are used, then no one in our lifetime should have to change them, except for the high use lower offs where the rope grinds through the metal over time, but that is just a maintenance thing.

If bolt holes are not reusable, there are several ways to fill them so they don't show much. You can use glue you already have if you are installing glue ins and apply dust and pebbles you have collected from the new hole you drilled. If you aren't using super red hilti glue and properly apply the dust, this can camouflage it well. Another option is epoxy putty like Damn Good Putty at about $19. You knead the two parts together, shove it in the hole, camouflage it with tiny rock chips or sand, and it is hard as the rock in 20 minutes. This comes in a few colors and other brands also have different colors. Any two part epoxy putty can work. LamLock Rocket Gel comes with the two parts and then 8 color bottles to get fancy if your rock isn't boring and grey, but this is expensive and bulky. InstaCrete is another great option and is only about $14. Clear silicone, in a squeeze bottle, can also be used if you smash a small pebble into hole after filling it with the silicone. Keep in mind the silicone and even clear epoxies, can yellow over time, so consider your rock color when doing this.

If you are using a mechanical bolt that relies on the hole being the correct size, you may have to drill the hole to the next size up. Oftentimes you are replacing a ⅜" (10mm) bolt and so you just go to ½" (12mm) for a fresh hole. Sometimes the bit can get jammed in there and so you have to baby it. If you are installing a glue in, then as long as it is the right size hole, not being perfectly cylindrical doesn't matter. However, additional drilling might be required if you need a notch.

Chop Chop

Some bolts can't be saved. They are so corroded the heads will snap off way before you could get the shaft out of the rock, or they get stuck as you try to extract them. Chopping usually is the term used for removing bolts in general and doesn't mean an ax is used, but this can mean use brute force to wack it so much it breaks. This would be more reasonable on really rusty bolts. Bolts with any substance that you can't use finesse like the other options we

have here can be cut off. The lightest and simplest way to do this is using a metal cutting hacksaw blade. Attach key rings to each side as handles. You can also use a battery powered angle grinder or Sawzall or get an wheel adapter that works on your drill called a Mandrel. This can be tricky to get under the hanger and/or not grind a half circle out of the rock. You can cut the bolt head off above the hanger, then remove the hanger and try to smash the bolt into the hole flush with the rock.

Sometimes you can just "over tighten" the bolt with a 18" breaker bar and ping! The head will snap off and will be ready to patch. SS studs break pretty easily, carbon steel has more elasticity and tends to be harder to snap. 5 piece bolts tend to spin in the hole before breaking. Either way this gives you insight on why we should over tighten them when installing!

Forking up - Button Heads

This is like chopping but with more finesse. A tuning fork, commonly made from pitons literally wedges bolts out. You start with quite thin blades then progressively work up to thicker ones and even stack them until the bolt is free. Of course a big enough crow bar would probably also work. Forking up more common on bolts that can't have drills attached to them or adapters + extractors such as button heads. I have used this method in Yosemite where drills are not allowed.

Be mindful not to damage the rock. Granite can sometimes take a beating but softer rock can get scared if you are too aggressive on it. A paint lid or sheet metal works or if a piece of wood if you are using a lever like a crow bar. It can be assumed that if you are trying to replace a bolt, you care about the end result looking nice, so be mindful about keeping the rock nice. We remove button heads with forks in this *PLAYLIST*.

Roll up your sleeves - Powers 5 piece bolts

Powers 5 piece bolts can be unscrewed and the core bolt removed, however the sleeve and nut is still stuck in there. Even though the nut fits snug in the hole, if the sleeve wasn't in the way, the bolt can be reinstalled and used to pull out the nut. The trick is removing that sleeve! With enough tears and patience, you can try using needle nose pliers to pull it out, hook it from the bottom, or smash and drill it into pieces with a concrete bit and your rotary hammer. If you are trying to grab the nut at the bottom after removing the pesky sleeve, then don't bust your nut up. You can pull the reinstalled bolt with a bolt removal tool that we discuss below, or just attach a shit hanger to it and use a funkness device (hammer with sling attached to head), or grind it to a pulp and blow it out and use a magnet tool.

Spinning (Step 1 of 2) - Wedge bolts

This is step1 of of a 2 step process. Wedge bolts can be spun to create a grove next to the clip at the base, stopping the clip from expanding and being able to "just" be pulled out. Adding water helps mix with the dust to create an abrasive paste at that point of contact. If you want to really get gritty, you can use 240 grit aluminum oxide sand blasting powder in a squirt bottle so you can get groovy faster. It can be tricky to get the right adapter to fit your drill AND the threads on the bolts. Once the bolt hits the set screw, inside the adapter, the bolt stops threading deeper inside the adapter and starts to spin the bolt itself. If the coupler touches the rock then the bolt won't spin. As you drill you push and pull like you are truly screwing the rock.

Powered spinning: If you use the rotary hammer drill you probably already have with you, then you need an SDS adapter to generally a male threaded end. Then you put a coupler on that which is female on both sides that goes on the male… ok i'll hold back the jokes. If you want more torque, you can use a 3/8" impact driver and that just requires a different adapter.

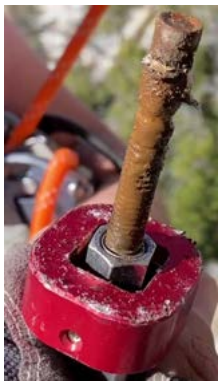
Manually spinning: Why on earth would you spin a bolt manually??? National Parks in the US don't allow power drills even if you are a do gooder who wants to re-bolt. This video shows the spinner tool that Dan Merrick modified for bolt spinning. It is a speed wrench + universal joint socket that goes over the coupler nut + coupler nut (with course threads!). These components need to be secured together because you will be pulling out while spinning it. There needs to be a set screw inside the coupler (or an extra nut on the bolt) because if the bolt doesn't bottom out in the back of the coupler it just pulls the bolt tighter against the clip instead of spinning it.

Extracting (part 2 of 2) - Wedge Bolts

Even with the base of the bolt compromised, it can still be surprisingly difficult to pull the bolt out. However, mechanical advantage can come in a small package. A giant screw inside a hollow tube is light and affordable, or a small hydraulic pump, that works very much like a car jack, gives so much advantage you have to pump carefully in order not to snap the bolt. If done correctly, there will be a clicking sound as the bolt comes out a little bit at a time. And if the tool doesn't have enough lifting distance (throw), then you just reset it and

put in a spacer and do it again. No one needs the BoltBusters crazy hollow ram puller unless you are trying to be dramatic! Something I learned with BoltBuster is more power isn't always what you want. Technique is important or you just end up snapping the bolt and then the hole cannot be reused.

Giant Screws - Greg German (Gregger Man) has developed a Doodad bolt extractor that is a like a giant screw inside of square tubing with an adapter on the end that gets attached to the threads on the bolt you are trying to remove, the giant screw grabs the adapter, the outer pipe or square tubing that it is inside of, pushes against the rock around the bolt while you spin the handel in the back sucking the bolt into the square tubing. Watch us use this tool in this episode. Watch Greg show you how to make one on his video or him using an older version in this video and him explaining about it in this video .



The Hurley Junior can also be either homemade or ordered from Access Fund and is a more compact screw type bolt extractor. This is another good video showing the tool.

Hydraulic Pumps - The outer part stays against the rock and the inside gets sucked up with hydraulic action. Hydraulics are amazing and that is how we do all our break tests in BoltBusters but we oversized everything for dramatic affect.

The Greenly Hydraulic Punch Driver is designed to pull dyes together to cut holes in sheet metal and can pull up to 7tons. It is super handy and comes at the low low price of a condo in Thailand, but luckily at $892 it comes with free shipping! If weight isn't an issue, it is an amazing tool at 14lbs with the adapters. Unless you have BoltBuster's hollow cylinder, these tools just don't have much stroke, so you pump a little, place a spacer under it and repeat. Hollow cores can also have adapters attached but require a hose and small hand pump but that isn't practical on a cliff face. You can watch the Access Fund use the Greenly in this video.

Getting Hot - Glue In Bolts

Glue, in theory, can be heated up with a blowtorch and then pulled out. We say theory because it's really hard to get the glue 4" down or even further hot enough to become weak enough to remove easily. If you can get the bolt out, then you can drill out the remaining glue and reuse hole. Try not to have too many flames next to your climbing ropes if you are hanging around while doing this!

Micro Core Drill - Glue In Bolts

Drill a very tiny hole around the sides of the glue in to loosen the glue until it becomes free. Drilling an equal size hole next to it doesn't really solve a lot since the rock is now compromised and you still have two holes at the end.

Getting Twisty - Glue in bolts

Crowbar in the glue in + twist = done. This can be hard to get some bars in the glue in's small space or the glue in head can wrap around the bar so you can't get it off without other tools. Also, this method can possibly break the bolt instead of disengaging it from the glue.

The Access Fund has a great bolt removal page that dives into detail on even additional bolts not covered here and has lists and kits you can reference in these photos here.

DON'T SUCK!

Bolts that you tried to remove, but couldn't, are now compromised. Make sure you can finish what you started AND replace them. Half finished work can be super inconvenient at best or kill people at worse. If you do suck, make the bolt and hanger unusable or put a note on it. Ideally practice at home before!

Keep Learning!

Unlike other bibles, we promote learning from other groups! Here are some fantastic resources that we learned a lot from.

MOUNTAIN PROJECT

- Mountain Projects Bolting Forum is where the community is at. Stay up to date with the latest knowledge, trends and questions by following this thread. https://www.mountainproject.com/forum/108887311/fixed-hardware-bolts-anchors

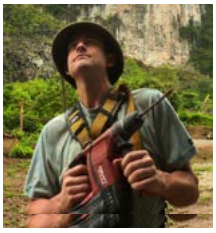
ACCESS FUND

- The Access Fund not only helps keep access to climbing crags, but also helps re-bolting efforts. https://www.accessfund.org/our-causes/replace-aging-bolts

asca

- ASCA - American Safe Climbing Association's mission is to replace deteriorating anchors on classic climbs in the US and educate climbers about the public about climbing safety. This link goes straight to their education section about bolts. https://www.safeclimbing.org/education.htm

- AAC - American Alpine Club has a grant program to help fund rebolting https://americanalpineclub.org/anchor-replacement-fund



- Francis Haden has a great all around resource that is like the abridged version of the Bolting Bible https://francishaden.wordpress.com/development/

- Find a bad bolt? Let these guys know! https://www.badbolts.com/

- Bolt-Products has a whole section dedicated to education and you can find that at http://www.bolt-products.com/Glue-inBoltDesign.htm

- Michael Law wrote a 59 page bolting guide called "Soft Rock Bolting Guide" but is for all bolting and pretty thorough. He also have done a lot of independent testing.
- Michael Law and Steve Hawkshaw published an official article in 2014 of their break tests that is available for purchase.
- He tests fire damaged bolts in this video
- He tests U bolts (staples) in this video

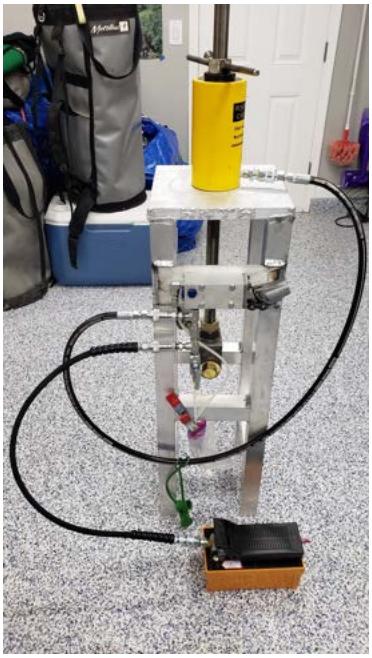
The Book of

NUMBERS

"Know how hard thou needest to tug it before you get release"

BoltBuster is a project that Bobby Hutton and I built to test climbing bolts in every scenario imaginable. We learned how hydraulic systems worked and how we could use them to generate well above 100kn to be able to destruction test any bolt test we wanted to. We have one machine that looks like a bar stool for testing in tension. It has a hollow ram hydraulic cylinder on top that lifts our long threaded rod that we attach to our dynamometer. To test in shear, we have a 4" hydraulic cylinder (like you would see on a tractor) that we anchor to the ground on one side and pull test with the other.

The Bolt Buster project is unique because of the following:



1) we try to be as sciency as we can afford with 3 samples of anything we test, AND
2) publish WITH EDITED VIDEOS <u>all</u> of our results,
3) we don't manufacture any bolts and therefore are independent AF.

We have NO sponsors, and we DON'T test in a lab with small blocks of cement simulating real world situations - we just go outside and pull bolts in an as realistic scenario as possible. See behind the scenes in this **EPISODE**.

Why test bolts that are certified and rated and have been tested already in labs??? You would be surprised what we find. We also are not trying to verify lab results but instead try to test all sorts of situations we would find ourselves using these bolts. Standards and labs are trying to eliminate variables so we can get the holy grail of the MBS (minimum breaking strength) and have that number relevant to other bolts or climbing gear. That has value in the manufacturing world but doesn't always properly inform the end user. As soon as we step outside of "normal use", which many times can be quite common, we can get very different results, and that is what we test. We have been curious ourselves about different variables but others have asked us numerous questions that we try to explore:

- What happens if you over torque the bolt? Or don't tighten it enough?
- Is it bad to oversize the hole when using glue ins? Is too much glue bad?
- What happens if you install a P shape glue in bolt backwards?
- What happens if you pull a glue in sideways?
- Is a ½" hanger bad on a ⅜" bolt
- Do you install the hanger below or above the flange on the Fixe Triplex bolts?
- Are concrete screws reliable?
- Are the shitty ⅜" PB+ bolts rated to what they claim?
- Are the welds weak on xyz bolts?
- Are off brand hangers on amazon safe?
- How strong are wave bolts WITHOUT glue?
- What happens if you don't clean a hole before gluing?
- Break tests in granite vs sandstone with the same bolts?
- What is the actual strength of AC100 vs epoxy?
- Is expired glue safe?
- Many bolts have 1 MBS number, what about pulling in tension?
- Do chains drastically reduce a bolt's strength (since it pulls higher up on the bolt)?

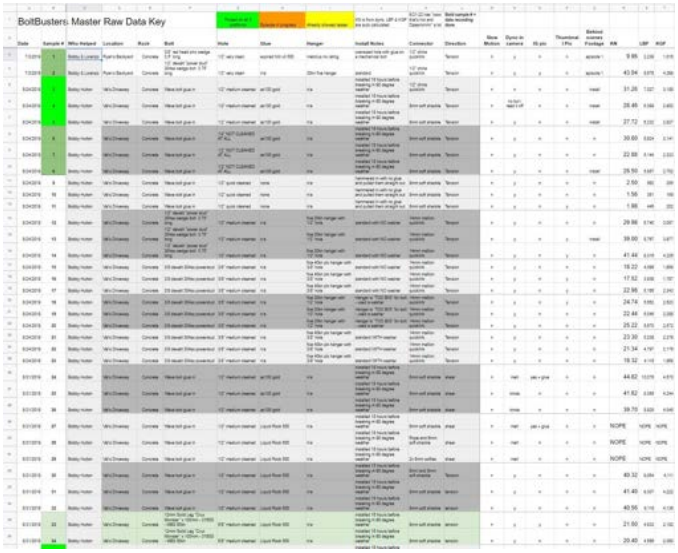
You would be surprised what we DON'T know about bolting as a community. We hope there is more light on our bolt knowledge after all our BoltBuster tests. You can learn more in 5 minutes watching our compilation EPISODE about how much you hate psytrance music... or HOW bolts break than most experienced bolters. This is 50 break tests in sandstone in super slow motion at 960FPS.

We do a lot of tests in concrete because it is much more convenient to set up this overly complex break test machine, install hundreds of bolts, pull them in a way that doesn't break our gear or our bodies and film every test with 3 cameras while recording over 10 points of data for each one. As long as heads snap off, hangers bust, or welds break… our concrete substrate is not affecting our results. We also have traveled with our machines to the middle of nowhere to test granite and sandstone. When we do test these areas, we angle grind what doesn't fully come out and cover with glue and dust our holes so you can't really tell we were ever there. We try not to damage any areas, but these tests also help educate those who are going to put in bolts that will stay to do a quality job or to bolt less if possible. Highliners for example were using 4 to 6 bolts for anchors, but this research has clearly shown that we can use 2 or 3 now.

Our goal is to break 1000 bolts and not any more of our break test equipment! As of writing this in March 2020 we are at 302 samples. Sometimes we get a break on retail price but no one sponsors these

tests, we don't get free gear and youtube videos for niche subjects don't make money. (50k views in a week on my most popular video made $37, most videos are under 5k views). So I'm hoping this $10,000 project is loved by all and supported by some to help curb the cost. Please ***Donate*** something on paypal if it has really helped you out or support our **Juno Coffee** business as we started a side hustle to stay away from making gear. We like to be independent AF. And of course, like any good Youtuber, we have **T-Shirts** for sale! Thanks!

If you are a data nerd and love spreadsheets then by all means, spend your friday nights staring into our raw SPREADSHEET that we fill out when we do our tests. But our focus is making short, info packed, entertaining videos so everyone can get the jist of what bolts break at and how. In this "Book of Numbers" we include a written version of the published episodes and the corresponding bite size chart. We will update this when we publish our Bolt Buster episodes.



HOW NOT 2 HIGHLINE

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Crux Monster Bolts

About the bolt: From www.bolt-products.com, these bolts are the largest rod available (12mm) which minimizes flexing for crack prone rock and gives the best bend radius for highline anchor rope if it is directly threaded through preserving more rope strength. They have an MBS of 60kn. It's not ideal to thread ropes inside these bolts for climbing anchors because replacing these bolts can be difficult, it is better to have a large quicklink attached that can be changed out after enough rappel abrasion.

Our Results: We used Hilti Hit 500 v3 epoxy glue that was either 6 months OR 2 years and 3 months expired and basically the welds break with very few bolts coming out. Test 265 came out that was cyclic loaded very high 4 previous times as we failed to break but it was also only installed 16 hours prior in very cold temps. Test 46 was the only one in Ac100 glue but the weld broke before coming out of the hole. Except for Test 265, all the tests broke the welds, even in wet sandstone where did not have any rock failure. Epoxy and stainless steel don't like each other very much so the bond relies on the groves but even then it still comes out eventually. We don't quite get 60kn in most shear tests but these are great bolts, the website should maybe just be changed to reflect a more conservative number. We got some really weird low numbers when we tested in tension in concrete. Our conclusion is these welds are very inconsistent but generally high enough that I will continue to use them.

Crux Monster Bolts		
Manufacturer: www.bolt-products.com.		
MBS: 60kn		
6 month expired Hilit v3 500 glue		
Hangframes in sandstone		
Test 265	**51.70**	Bolt pulled out
Test 266	**45.42**	Weld broke
Test 267	**45.26**	Weld broke
Tension in sandstone		
Test 268	**36.52**	Weld broke
Test 269	**42.68**	Weld broke
Test 270	**41.74**	Weld broke
Test 276	**37.60**	150mm Long bolts, weld broke
Test 277	**40.84**	150mm Long bolts, weld broke
Shear in sandstone		
Test 221	**50.00**	Weld broke then bolt pulled out
Test 222	**57.16**	Weld broke
Test 223	**52.20**	Weld broke
Tension in WET sandstone		
Test 276	**37.60**	100mm bolt, weld broke
Test 277	**40.84**	150mm bolt, weld broke
Shear in concrete		
Test 46	**59.60**	Weld broke then bolt pulled out of AC100 Gold
Test 55	**82.50**	Weld broke
Test 56	**66.38**	Weld broke
Tension in concrete		
Test 33	**21.50**	Weld broke
Test 34	**20.40**	Weld broke

Titan Eterna

Titan Eterna		
Manufacturer: www.titanclimbing.com.		
MBS 35kn 80mm long		
6 month expired Hilit v3 500 glue		
Installed 16 hours prior in 50F degrees		
NOT notched during install		
Shear in Granite		
Test 170	**36.52**	Eye broke
Test 171	**42.68**	Eye broke
Test 172	**41.74**	Eye broke
Tension in Granite		
Test 173	**51.70**	Eye broke
Test 174	**45.42**	Eye broke
Test 175	**45.26**	Eye broke

About the bolt: Certified titanium glue in bolt installed in a 14mm hole and has an interference near the top so it won't slide out of the hole while the glue is curing. MBS is 35kn and each bolt is proof loaded to 12kn.
Our Results: We did not install these with notches but it is the recommended method. None of the bolts came out of the granite but the eye broke and it did above the MBS every time even when pulling in tension. It sparked every time it broke. They would start to bend at 8kn but they were not notched. We think we would get 10kn to 12kn before bending if it was notched.

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3/8" Split Shaft

3/8" Split Shaft		
Donated by Greg Barnes (ASCA)		
Mushroomed top during install		
Zinc plated - not recommended		
Shear in Granite		
Test 176	**37.50**	head snapped
Tension in Granite		
Test 183	**22.52**	head snapped
Test 184	**17.12**	head snapped

About the bolt: These are used in construction and no longer in climbing. They generally only come in zinc plated and most of these placed 10 and 20 years ago are being pulled out and replaced. ¼" button heads were pretty common and are way too tiny for today's standards. This split shaft is threaded on the top but we had to smash it in so tightly that it mushroomed the top of the bolt making replacing the hanger in the future impossible.
Our Results: I was not shocked the head snapped in shear but was shocked that it also snapped off in tension before pulling it out. They are pretty strong but only when new as corrosion would reduce the strength over time.

Fixe Hely Glue In

Fixe Hely		
Manufactured by Fixe Hardware		
PLX steel with MBS of 28kn		
Installed 24 hours prior		
4 month old expired Hilti 500 v3 glue		
Shear in Concrete		
Test 121	**30.94**	head snapped
Test 122	**29.80**	head snapped
Test 123	**27.74**	head snapped
Tension in Concrete		
Test 115	**26.98**	head snapped
Test 116	**26.96**	head snapped
Test 117	**28.66**	head snapped

About the bolt: Fixe Hardware's newest glue in bolt is forged, made from PLX/HCR duplex stainless and fits in a 38" or 10mm hole. These do not require a notch and the shape of the shaft helps the glue grab the bolt. The eye is rounded so ropes could be ran through the eye of this glue in.

Our Results: In tension and in shear, it consistently broke right below the surface of the concrete right around MBS. Our results were fairly consistent because there is no weld to add a variable. The website shows 28kn MBS is for 3 directions but tensions didn't give us a full 28kn every time. The episode above only shows our shear tests but our newest episodes show both shear and tension in the same episode now.

Horizontal Hangers

Horizontal Hangers		
By FixeHardware		
Plated Steel tested with MBS of 18kn		
Bolt was Simpson TitenHD 4" screw		
Shear in Granite		
Test 91	**20.74**	hanger broke
Test 92	**21.22**	hanger broke
Test 93	**20.20**	hanger broke

About the hanger: Fixe Hardware's sells a hanger designed for climbing lower offs. You add one quicklink to these and the rope will run parallel to the rock rather than getting smashed against it. They do sell these with welded rings inside. If two of these are spaced too far apart on an anchor it causes a rope to get gnarly twists in it. We tested PS accidently and not their 304SS hanger which is rated for 26kn. Please only use stainless steel!

Our Results: We installed these with Simpson Titen HD concrete screws like we did for all our hangers. They are ⅜" and fit in a ⅜" hanger and a ⅜" hole and easily removable so perfect for testing hangers. There is no point in testing this in tension, but our shear tests were all consistently about 2kn above MBS.

Dewalt Power-studs

Dewalt Power-stud		
1/2" wedge bolt		
304 Stainless steel 3.75" long		
Fixe ss hangers were used		
Shear in Concrete		
Test 67	**48.88**	hanger broke
Test 74	**N/A**	machine maxed out
Test 79	**60.92**	bolt broke
Tension in Concrete		
Test 12	**29.98**	concrete failed
Test 13	**39.00**	concrete failed
Test 14	**41.44**	concrete failed

About the bolt: Dewalt makes a quality stainless steel wedge bolt that comes with a stainless washer and nut.

Our Results: It was very difficult to break these because if the hanger wasn't failing, our concrete was, or our original hydraulic wasn't strong enough. Test 79 we were able to break it at 60kn and that was lucky with a 30kn hanger! We love Fixe hangers. This bolt is awesome for hard rock, but didn't do so well in our sandstone tests which will be in a separate episode. They are about $3 a piece on Amazon.

3/8" Red Head

3/8" Red Head		
Zinc plated - not recommended		
Fixe ss hanger was used		
3.5" long		
Shear in Concrete		
Test 76	**20.50**	head snapped
Test 77	**22.24**	head snapped
Test 78	**19.22**	head snapped

About the bolt: Red Head is a cheap brand and their plated steel bolts are tempting to use because they are so cheap. A similar bolt was installed in the Blue Mountains in soft rock and killed someone. Short wedge bolts in general should not be installed in soft rock. This **VIDEO** shows how easy they removed them.

Our Results: Brand new, these did break near 20kn but cyclic loading and time would wear these out. Please use quality brands like Dewalt or from our climbing bolt manufacturers and only use this style in hard rock. The hanger we attached regularly gets 40kn so let's use a bolt that utilizes that value.

Fusion Hangers

Fusion Hangers		
Offbrand on amazon		
304SS hanger with MBS of 30kn		
Bolt was Simpson TitenHD 4" screw		
Shear in Concrete		
Test 97	**31.10**	hanger broke
Test 98	**29.56**	hanger broke
Test 99	**31.22**	hanger broke

About the hanger: These are found on Amazon for $5 a piece. They are a brand I have never heard of before but look legit and is 304SS.

Our Results: Tested with the TitenHD concrete screws which were bomber for our hanger tests. We did not test these in tension because we didn't feel it was worth it. MBS is 30kn but one of our tests was slightly below that. They seem fine if people want to use them but I would rather buy a PLX from Fixe for $3.35 which are twice as strong in our tests and more corrosion resistant.

Fixe Glue Ins with Hilti Glue

Fixe Glue In		
PLX steel with MBS 35kn		
Hilti 500 v3 glue expired 4 months prior		
Installed 24 hours prior		
10mm x 80mm		
Shear in Concrete		
Test 124	**55.88**	Pulled out
Test 125	**60.02**	Pulled out
Test 126	**49.70**	Pulled out
Tension in Concrete		
Test 118	**63.54**	Pulled out
Test 119	**45.78**	Weld broke
Test 120	**56.24**	Weld broke

About the bolt: [Fixe Hardware] has sold these bolts for years. They are a great glue in with a nice bend radius and welded really well. These do require a notch and that does help keep the weld covered from exposure. I believe they are making these bolts all PLX from now on. They cost about $9 each.

Our Results: We installed these 10mm bolts in a ½" hole into our concrete slab with the weld facing away from the force. Epoxy does not stick to stainless at all, so the bolt has notches, but it still fully pulled out of the glue, albeit at very high force. Only some of our tension tests broke the weld. The epoxy was 4 months expired but gave good results. We cannot recommend expired glue since that is really hard to determine how long is super safe enough. Don't risk people's lives to save $20.

Fixe Glue Ins with Liquid Rock 500

Fixe Glue In		
PLX steel with MBS 35kn		
Liquid Rock 500 new		
Installed 16 hours before on hot day		
10mm x 80mm		
Tension in Concrete		
Test 35	**45.78**	Weld broke
Test 36	**41.60**	Weld broke
Test 37	**41.12**	Weld broke

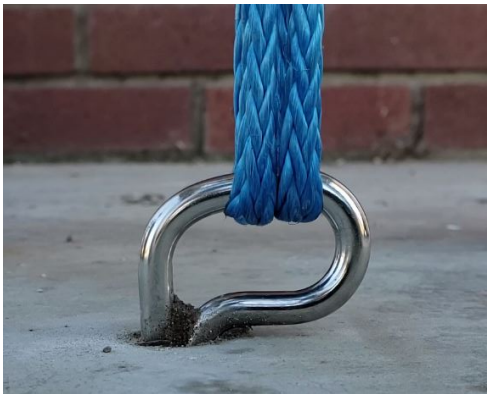
About the glue: Liquid rock 500 is an affordable epoxy with decent working times. We accidently found out that it will not come out of the tube when it is cold out. Hilit glue has been popular so we tested the same Fixe Glue in bolts as the test above, but with them in Liquid Rock 500 to see if it held about the same.

Our Results: The weld broke each time and the bolt did not come out of the glue. There is no point in testing in shear if the weld is going to just break. We also did other bolts in tension and shear and the bolts would break before coming out. This glue is fantastic if you are not wearing a puffy jacket! Dries way quicker than Set XP which is what I use to use. I like how it uses a normal caulk gun.

Wave Bolts with Dirty Holes

Wave Bolts		
Dirty Holes!		
Ac100 glue, 18 hours prior, Hot out		
Tension in Concrete		
Test 6	**30.80**	pulled out
Test 7	**22.88**	pulled out
Test 8	**26.50**	pulled out

About the bolt: Wave bolts are very popular 6mm continuous stainless rods bent with a wave shape on the shaft. They fit in 1/2" holes but require a lot of smashing with a hammer to get them in. They even have a tendency to bend while you hit them. The small bend radius reduces the strength of ropes threaded through them but is better for carabiners clipped to them than sharp hangers. Rarely are they installed with the intention of ropes being threaded inside of them.



Our Results: We tested the wave bolt with ac100 glue which is a very common glue used with these, BUT we did NOT clean the hole to see if the glue would come out in a cylinder like we have seen in some photos we shared in the Book of Holes section. Nothing seemed compromised and we got the same results as clean holes except the 22kn result was because I had an air bubble when installing that bolt. That shows how important it is that the entire hole is filled with properly mixed glue. Holes SHOULD be cleaned but this was interesting it did not affect this test. With results like this it wasn't worth testing dirty holes in this context in shear.

Wave Bolts with AC100 Glue

Wave Bolts		
Clean Holes		
Ac100 glue, 18 hours prior, Hot out		
Tension in Concrete		
Test 3	**31.26**	pulled out
Test 4	**28.46**	pulled out
Test 5	**27.72**	pulled out
Shear in Concrete		
Test 24	**44.82**	bolt broke
Test 25	**41.62**	bolt broke
Test 26	**39.70**	pulled out

About the bolt: Wave bolts are very popular 6mm continuous stainless rods bent with a wave shape on the shaft. They fit in 1/2" holes but require a lot of smashing with a hammer to get them in. They even have a tendency to bend while you hit them. The small bend radius reduces the strength of ropes threaded through them but is better for carabiners clipped to them than sharp hangers. Rarely are they installed with the intention of ropes being threaded inside of them.

Our Results: We tested the wave bolt with ac100 glue which is a very common glue used with these, we DID clean the hole unlike the test on the previous page. We got consistent results in tension as the previous test and the bolt, even with it's wave shape, does not stick to the glue once a certain force is achieved. I'm impressed with the shear strength and the bolt was breaking and pulling out around the same force so I assume epoxy would have the similar results. In theory, epoxy glue would last longer than ac100 but it is more runny and the ac100 is more user friendly though your working time is short!

You made it to the end!
Congratulations!

If you have feedback for additional information, more correct information or just good ol' typos that need fixing, please send it to me at skylining@live.com. I make a journal of it throughout the year and update it when we revamp it each time.

HOW NOT 2 HIGHLINE

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Juno COFFEE

If you read this whole book and it helped you please ***Donate*** on paypal or support our **Juno Coffee** startup or purchase **T-Shirts**! If all you can do is send positive stoke to our inbox, we love that too!

Check out our other great resources on www.HowNOTtoHighline.com