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Rigging Equipment

Sumidero Matarocas, Chile

Ropes

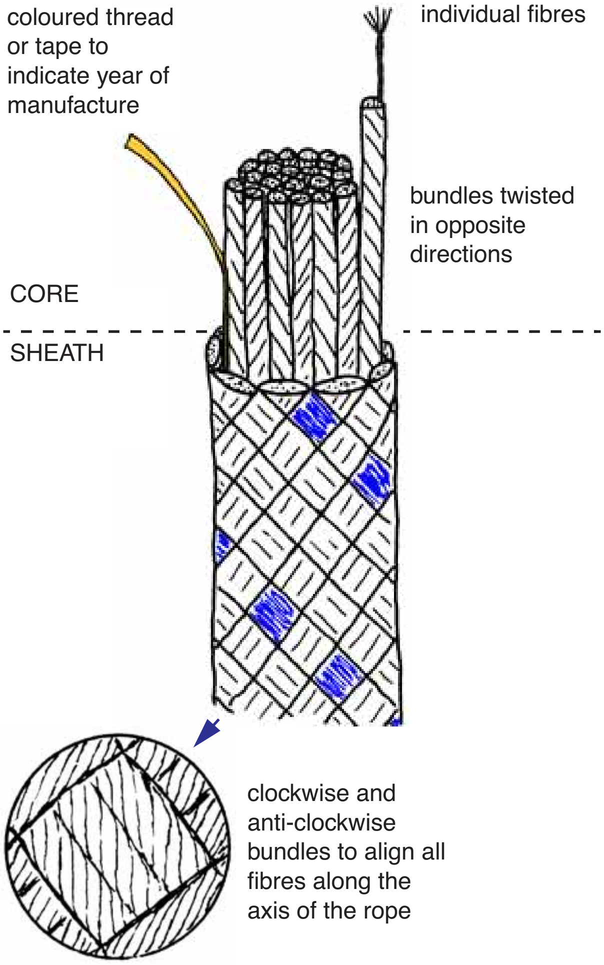
The rope is usually the weakest link in Single Rope Techniques and one that rarely has any back-up. For this reason alone, caving rope should be of the highest quality and treated with care. There is a dazzling range of ropes available but which one is the best has been a source of spirited debate for many years.

Construction

Kernmantle rope under construction (Beal factory/website)

Caving ropes have a 'kernmantle' or core and sheath construction. The core is the load-bearing portion of the rope as well as constituting most of the rope's strength. It forms about 60% of the rope and is usually made of several bundles of fibre, half of which are lightly twisted clockwise and the other half anticlockwise to stop the rope from spinning when it is loaded. Many ropes have a single coloured thread in the core to indicate the year of manufacture. Unfortunately the colours have not been standardised between brands and countries, and unless the information is printed on the tape, you must contact the manufacturer to find out which colours they have used.

The core is protected by a sheath made of 16 or more bundles of fibre that are plaited to form a tube around but not attached to the core. The sheath fibres may be straight or they may be lightly twisted so as to run along the axis of the rope to increase abrasion resistance. When a rope is in use the sheath takes the wear while the load bearing core remains intact.



Kernmantle rope

A loose sheath gives a soft rope that flattens when used and generally wears badly. A loose sheath may also creep down the rope and the excess slide off the end of the core. If this happens, descend with the rope hung the same way up for the first few times to force all the excess sheath off, then remove the 'tail' that has formed. If this tail is excessive (more than 50 cm in 50 m), or the sheath continues to slip after two or three wettings, try a better rope! The sheath can also be plaited very tightly to improve abrasion resistance and reduce dirt penetration, but makes the rope stiff and hard to handle. Fortunately most ropes lie between these two extremes.

The sheath is also the part of the rope to which ascenders and to a lesser extent descenders are attached. An excessively thin or loose sheath is dangerous because it may prove inadequate in protecting the core and because, if it fails with a caver attached, both caver and sheath may slide freely down the core.

Several rope makers have tried variations to the kernmantle design with things such as double sheaths, low stretch mini-cores and plaited core-bundles to improve desirable properties. One rope was even made with the core encased in a waterproof membrane intended to reduce its water absorption!

Material

Almost all caving ropes are made of nylon because of its suitable strength and shock absorbent characteristics. In most ropes both the core and the sheath are made of the same nylon – possibly with some of the sheath bundles coloured to identify the rope.

Avoid pure polyester (Terylene) ropes due to their exceptionally low shock resistance. Polypropylene and polyethylene are **NOT** suitable for SRT ropes but are good for canals and pools where a cheap floating rope is useful.

Some experimental ropes have been made with a low stretch mini-core of Kevlar or polyester in an attempt to give the rope good static as well as dynamic properties. The results have been varied but so far none have remained on the caving market for long.

'Super-fibres' such as Kevlar and Dyneema/Spectra don't yet make the grade, tempting as a 5 mm, 14 g/m rope may be. Their low stretch makes them dangerous under shock loads. Kevlar work-hardens and the sheath is so thin it can easily cut and slide down the core. Dyneema/Spectra has similar strength and stretch to Kevlar and also shares Kevlar's non-existent shock absorption. It does however have exceptional abrasion resistance, a sheath you could prusik on and doesn't suffer from work hardening as does Kevlar, is very slippery, but would melt on a hot descender.

Properties

Some rope properties are critical but most amount to a matter of convenience or personal preference. The properties that are most important depend on whether the rope is intended for Alpine or IRT style rigging and the skill of the user.

CE certification

A, B & L classifications

CE certification covers just about everything you buy in Europe, especially when it comes to safety equipment. Without going into details, "If it's CE approved, it's safe to use" is a good way to look at any equipment. One effect of this is that there are two main classifications for CE 'semi-static' ropes. Type A is based on a 100 kg load, while type B is based on an 80 kg load. Type L is a special lightweight category specified by the French Speleological Federation (FFS). Type A is most suited to use by commercial riggers and heavy use/fixed rigging and rescue. Type B suits lightweight sports caving and expeditions, and type L is for experts only. 'Static' ropes now bounce more than they used to in order to absorb the higher loads. 80 kg is still a good practical load for caving rope testing.

Table 2:1 **Summary of standard EN 1891**

Type	A	B
Diameter	9 to 16 mm	9 to 16 mm
Static resistance	2200 kg minimum	1800 kg minimum
Static resistance with fig-8 knot	1500 kg 3 minutes	1200 kg 3 minutes
Number of falls	5 falls factor 1 (100 kg)	5 falls factor 1 (80 kg)
Impact force (Factor 0,3)	< 600 daN (~600 kg)	< 600 daN (~600 kg)
Extension between 50 & 150kg	<5%	<5%
Sheath slippage	20 - 50 mm (Diam. Dependent)	15 mm maximum (0.66%)
Shrinkage in water	No limit	No limit
From Beal website (www.bealplanet.com)		

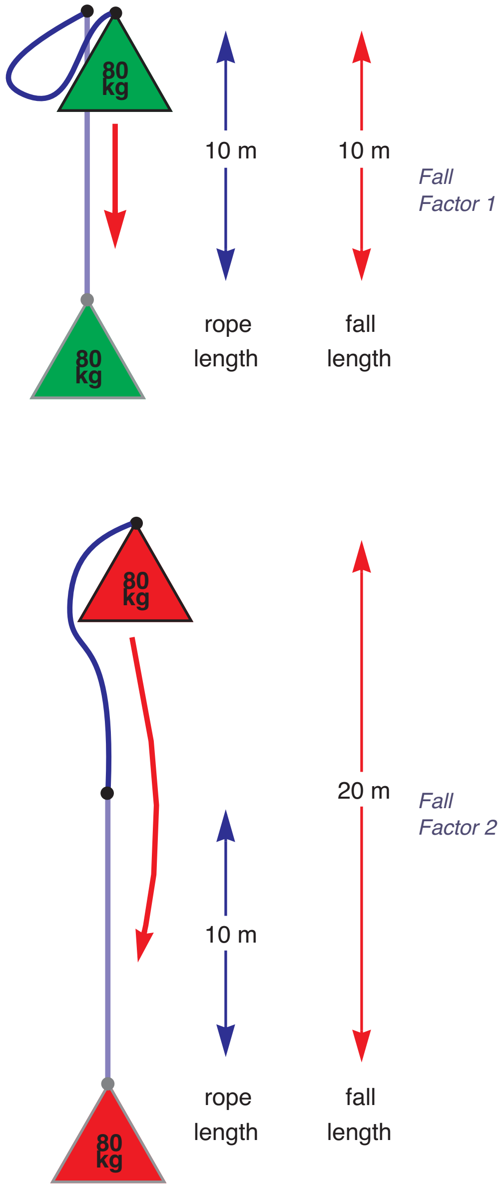
EN 1891 is a CE standard and doesn't apply outside Europe. Non-european rope may or may not comply with a similar standard. This in no way means that such ropes are inadequate or unsafe, just that it may be difficult to know exactly what you're buying.

Strength

The quoted "strength" of a rope is its Ultimate Tensile Strength and is obtained by gently increasing the load on a dry, new rope until it fails. Each end of the rope is wrapped around smooth, large diameter bars on the test machine to eliminate small radius and knot effects. Such a test has little to do with the way a rope is loaded in a cave. A rope's strength is of relative value for comparing strength losses and ropes to one another.

Any new caving rope must have a minimum breaking strength of 1500 kg. This allows for the strength losses caused by knots, wetting and poor rigging and still leaves the rope with an adequate margin of safety, provided it also has sufficient shock resistance.

Shock resistance



The most practical way of assessing a rope's strength is to subject it to a drop test. This is similar to what it may suffer in extreme caving situations. For example, when a caver slips at the top of a pitch and falls some distance before the slack in the rope takes up, or when an anchor fails and the caver takes a fall onto the back-up anchor.

The severity of a fall is often described in terms of Fall Factor (FF) with a standard 100 kg weight for CE type A and 80 kg for CE type B. The Fall Factor is the ratio between the length of fall and length of rope, eg. If an 80 kg caver is tied onto 10 m of rope and falls from the belay until he is stopped by the rope 10 m below, he subjects the rope, belay and himself to a FF1 fall. If he is 10 m above the belay and falls 20 m before stopping he incurs a FF2 fall, the maximum possible and hopefully non-existent in caving. In caving, the rigging and how you use it should only ever risk a maximum FF 0.3 fall so FF1 test provide a good margin.

Theoretically, the fall length is irrelevant. A FF1 fall of 0.5 m onto a cowstail is as severe as a FF1 fall of 30 m (30 m rope will have about 60 times the rope to absorb the shock of a fall that is about 60 times as far).

In practice this is not quite so, as there is an 'end effect' of knots tightening and harness and body absorbing shock that effectively reduces the severity of falls under 1.5 m.

An 80 kg weight is a standard so that ropes can be compared, heavier weights cause more severe shocks in drop tests.

Drop tests using 2 m of rope knotted to form a length 1 m long consistently show that new, dry static ropes rarely survive more than one FF2 fall, if that. Most will survive several FF1 falls but after each fall the rope loses elasticity and becomes progressively less able to absorb future falls. ie. The first drop may generate a load that is 50% of the rope's breaking strength. The second 80%, the third 100% —until it breaks without an appreciable loss of 'strength'.

The shock resistance of a rope—its ability to survive falls—is largely a factor of its stretch, or more precisely its 'elongation under load'. As a rope catches a fall it stretches and absorbs the energy released by the fall. Greater stretch means more energy absorbed over a greater distance and less load applied to the anchor, rope and falling caver. People too have a limit as to how much force they can withstand. The absolute maximum for human shock resistance is 1200 kg for a fit individual in full-body harness. Anything over 600 kg may well injure you. That is, the rope must arrest a falling climber without the load ever reaching anywhere near 1200 kg. Caving falls of < FF1 are unlikely to generate this amount of force. However, the static properties of caving rope mean that the 1200 kg limit and possibly the breaking strength of the rope would be exceeded by a FF2 fall—the CE standard for climbing ropes. Indeed many caving ropes would not even survive a load of 1200 kg when tested under cave conditions!

A new caving rope must be able to survive two or more FF1 falls

The lack of shock resistance of caving ropes could well persuade you to use the strongest rope available but a very strong rope is not necessarily safe unless it can absorb FF1 falls without exceeding the 1200 kg limit.

Remember that a FF1 fall on 1 m of rope is only a comparative test with a built in safety factor and virtually cannot occur in caving even with poorly rigged ropes (see page 57).

Take a worst case of two bolts rigged 15 cm apart at the same level with a 1 m stand-in loop between them —yes, they do exist! If the critical bolt fails when you are connected directly to it or perhaps just below it you will attempt a 2 m, FF1 fall but will not succeed. The knots and loops at each end will absorb some energy, just as in test samples but what is more important, your body and harness will absorb around 30% of the energy. There will also be some pendulum effect and no doubt you will fall outwards or crash into the wall and so absorb even more energy. Perhaps you would occasion a FF0.6 fall—serious enough if the rope was not up to standard but still well short of FF1. The same two bolts rigged correctly with no more than 30 cm of rope between them and taking into account the mitigating factors would be unlikely to take a FF0.3 fall. This gives a good safety margin considering that FF0.3 is the maximum expected for well rigged ropes.

The most convincing evidence that caving ropes are strong enough is the complete lack of accidents due to ropes failing under shock loads and this includes old design polyester ropes that have extremely low shock resistance compared with nylon ropes.

Stretch

Static ropes are often defined as those that have less than 4% elongation under a load of 80 kg when new and dry. Manufacturer's stretch figures often differ considerably from reality and most ropes are stretchier than claimed with the percentage stretch increasing over the first few uses. Prusiking up a rope with more than 4% stretch is like climbing a giant rubber band. Apart from being uncomfortable, excessive stretch makes rigging difficult, increases sawing on rub points and the possibility of hitting something as the rope takes up in a fall. On the positive side the shock-absorbing capacity of the rope is directly related to its stretch.

Insufficient stretch (less than 2%) is marvelous for prusiking, makes rigging easier, reduces abrasion problems caused by sawing but could make the rope dangerous if subjected to a shock load. A lack of stretch means a greater force will be generated in the event of a fall. For example—some polyester ropes have very little bounce and are a dream to prusik on. This gives them such low energy absorbing properties that even a FF0.2 fall could exceed their strength. A low stretch, superstrong rope just transfers the shock to the anchors and caver on the rope.

There must be a trade-off. Static ropes are used largely as a matter of convenience but it cannot be taken so far as to prejudice safety (see Table 2:4 on page 27).

Diameter and weight

The diameter of a rope will affect most of its other properties. Caving ropes range from 7 mm to 11.5 mm in diameter and those over 8 mm are all safe

when rigged appropriately.

When choosing a rope, consider the manner in which you will rig it, the weight of the rope and the space available to carry it. If weight and volume are no problem a thick rope is better; it will last longer and will allow a greater margin for error over a thin rope. If the rope is to be carried up a mountain or down a deep cave you cannot ignore the weight advantages of 8 mm or 9 mm ropes.

Table 2:2 **Rope diameter and rigging style#**

Rope (mm)	Rigging Style				
	IRT	Alpine	Ultralight	Cord Technique	Climbing*
11	ideal	fixed rigging	too heavy	too heavy	ideal
10	marginal	general	too heavy	too heavy	CAUTION
9	DANGER	sport/ exploration	heavy	adequate	CAUTION
8	NO!	sport/ push rope	ideal	ideal	DANGER
7	NO!	NO!	Expert Alpine cavers only		NO!

* Dynamic rope only, 9 mm or thinner ropes must be used double
\# Rigging styles are discussed in Chapter 4.

Some cavers have taken the obvious weight reducing step and use 7 mm rope. To my knowledge no rope under 8 mm satisfies the minimum 1500 kg breaking strength requirement. However, if you find one sufficiently elastic to survive two or more FF1 falls, by all means use it **with extreme care**.

With thin rope there is no choice when rigging, it must be perfect Alpine style. Thin rope wears out more rapidly than thick rope and cost more in the long run because of its shorter life-span (see Table 2:4 on page 27).

Flex and handling

The flex of a rope is partly due to its diameter and partly due to its construction—mainly the tightness of the sheath. Soft flexible ropes are more pleasant to handle, knot and pack better than stiff ropes.

In Mexico they call rope "cable"*...*

Any rope will stiffen with use and lack of cleaning, and obviously a rope that is stiff when new will have a head start. A rope that does not bend enough to pack efficiently into a rope sack can be made a little more flexible by wetting it. If space is at a premium, favour must be given to pliable ropes, but this has a limit—very soft rope generally has low abrasion resistance as well as often suffering from sheath slippage.

Abrasion resistance

Many cavers consider abrasion resistance the most important characteristic of a caving rope. All commercially available caving ropes and most climbing ropes are adequate when rigged appropriately. The question is more one of the life-span/cost of the rope rather than one of safety.

When correctly rigged, Alpine style causes no immediate abrasion problem. IRT uses a thick rope that by its bulk should handle the immediate problem of an abrasion point. In both rigging styles though, there have been numerous incidents due to bad rigging and poor judgement of abrasion points and just plain accidents.

"After prusiking some distance, the rope lost its bounce as if I was approaching a rebelay. I looked up to see if I could see it with my light. What I saw baffled me. Instead of the rebelay with the compulsory loop of rope to the side I saw the rope move quickly up and down on the wall, caught on a spike. I could see in the dimness that there were furry bits sticking out from the rope.

I stopped moving and braced my legs against the wall to try and get a better look. This enabled me to stand up straighter and I saw the rope come to a stop in its see sawing against the wall and it went 'twang'. I swung in a pendulum further to the left...

...Centimetres from my lead ascender, the 8 mm rope was shredded at one point to four very skinny threads, two of them rubbed and the sheath broken and completely in ribbons."—Carol Layton in *Caves Australia* 170.

Generally, hard and thick ropes are more abrasion resistant than soft and thin ropes. Thick rope has greater bulk to cut through than thin rope and each fibre is under less tension and so is more difficult to cut (try cutting a slack rope with a sharp knife, then see how easy it is to cut when under tension).

As already mentioned there is a sawing effect as a rope moves up and down with the changing loads caused by prusiking and rough abseiling. More sawing will inevitably occur on longer drops. Sawing does not spread the wear, as old time users of bouncy laid ropes once insisted. It increases the wear and is a major reason why dynamic ropes are less suited to fixed rigging than static ropes.

Some manufacturers have improved their rope's resistance to abrasion by increasing the tightness of the rope sheath and its bulk in comparison to the core. Such 'improvements' make the rope hard and difficult to handle as well as reducing its shock absorbency.

Abrasion resistance can also be improved by twisting the sheath fibres so that the left trending bundles are twisted to the right and the right trending bundles are twisted left. This aligns all exposed rope fibres along the axis of the rope thereby rendering them less easily cut as the rope moves up and down against the rock. For the much less common problem of sideways movement such construction would possibly lose some resistance.

Shrink

It is an unfortunate fact that nylon ropes shrink up to 15% (lengthwise) during their first few wettings and dryings. This is unavoidable and all you can do is to buy ropes 15% longer than the length needed and to make allowance when you rig new rope so that it does not pull tight between rig points or lift off the floor of long pitches as it shrinks.

Water absorption

A soaking wet nylon rope is about 35% heavier than its dry counterpart and takes some days to dry out completely. In some cases it is worth packing a long rope in a plastic bag to keep it dry and it is always worth stacking a pack of wet rope upside down whenever possible to allow it to drain.

Table 2:3 Rope strength when wet*

Age	Wet/Dry	FF1 Falls (80 kg, 1 m)
new	dry	41
new	wet	25
4.5 years	dry	4
4.5 years	wet	4

* Tests on 9 mm Bluewater II

Water affects nylon rope, making it less abrasion resistant than dry rope and reducing its static and shock strength by up to 30%.

Melting point

The nylon used in caving ropes melts at between 210° C and 250° C, depending on the type. A more relevant figure is the softening temperature: about 150° C. Above this temperature the rope becomes soft enough to pull apart under a caver's weight. Fortunately it is almost impossible to do this in the caving situation. Most descenders are capable of reaching instantaneous temperatures high enough to melt the fuzz on a rope but the volume of hot metal in the descender contains insufficient energy to melt the entire rope. When abseiling fast on dry ropes it is possible to superficially glaze the rope sheath. Petzl Stops are very prone to this because the stainless steel lower pulley heats up very quickly. Fortunately, it also cools very quickly! Provided you don't remain in one spot with a hot descender this does little structural damage to the rope.

Chemical deterioration

Nylon is a polyamide polymer. That is, it is made of long chains of molecules with the chains linked to each other less strongly. With time, these polymers slowly disintegrate to form simpler structures. Chlorine has adverse chemical effects on many polymers so never allow chlorine bleaches and washing powders that contain it to touch your ropes. Many substances commonly found in garages and car boots have drastic and possibly invisible effects on nylon—be especially careful of acids, solvents, paints and any concentrated solutions.

Ultraviolet radiation in sunlight accelerates polymer disintegration but fortunately caving does not involve much sunlight. Nevertheless, avoid drying ropes in direct sunlight, leaving entrance pitches permanently rigged, and always store ropes in the dark.

Mechanical deterioration

Quite apart from the effect of dirty descenders grinding the rope sheath, the constant intricate bending under load that a descender gives the rope has no measurable effect on the strength of its nylon.

Kevlar however, can lose 75% of its original strength after 100 descents! Possibly a more insidious physical deterioration could well be caused by the minor shock loads caused by prusiking, rough abseiling, etc. Just as a caving rope may be seriously weakened by two FF1 falls could it also be damaged by twenty FF0.1 falls? Perhaps an avenue for investigation, in the meantime, cave gently.

Dirt absorption

Dirt in the form of mud and tiny crystals slowly makes it's way into ropes, but exactly how far it gets and what harm it does is highly variable. Cut open an old rope, even a dirty one, and the core is usually quite clean. The sheath is a very effective filter. A lot of dirt in the sheath makes the rope stiff and unpleasant to handle. It probably also cuts some of the rope fibres and weakens the rope, but contributes more to wearing it out faster than it should rather than making it unsafe. The core rarely gets enough dirt in it to cause any real problem.

Age deterioration

The effect of time on the strength of nylon rope varies greatly with the researcher. One claims 50% strength loss after only ten uses (Smith, 1980) while another assures us that there is no loss of strength over two years! (Stibranyi, 1986). The most consistent indications are that ropes rapidly lose shock resistance with age —used or not, though heavy usage will further accelerate the degradation. Take the pessimistic view and assume that within a year your rope will be only half as strong as when it was made. This may even have occurred by the time you buy it. It is interesting that while absolute strength deteriorates with age and/or use the percentage effect of knots and wetting diminishes with age. ie An old rope is almost as strong wet as it is dry, whereas the same rope when new is considerably weakened by wetting (see Table 2:3 and Table 2:4).

Table 2:4 **Rope strength with age***

Age	Condition	FF1 Falls (80 kg, 1 m)
new	unused	41
6 months	approx. 40 ascents/ descents	10
4.5 years	worn, stiff	4

* Tests on dry 9 mm Bluewater II

A rope is only new once, its strength diminishes rapidly with its first few uses or wettings and dryings, thereafter the rate of strength loss slows considerably. Table 2:3 and Table 2:4

show how age and water can affect a rope, and these are an unavoidable part of using the rope in a cave. Even to perform the tests the rope strength had been reduced considerably by tying knots in each end of the rope.

Table 2:5 **New rope comparison**

Diameter	Av. Weight (g/m) Dry	Wet	Stretch * 80 kg (%)	Metres in 25 L sack	Static* Strength (kg)	FF1 Falls* 80 kg, 1 m
11	75	98	1.25	75	3000	10+
10	62	81	2	100	2500	8 - 20+
9	50	65	3	120	1800	3 - 10+
8	38	49	4	180	1500	2 - 3
7	33	43	4	220	1000	0 -2

* Figures from manufacturers and suppliers catalogues
Note the difference in shock resistance between ropes above and below 10 mm.
This indicates that you must exercise much greater care when selecting and using 'thin' ropes instead of 'thick' ropes.

Strength loss is possibly connected with changes in other characteristics such as loss of handling properties and flexibility. Fibres don't move past each other as easily as when a rope is new and friction increases. Treat old stock as used rope and not as good as 'this year's model'. Treat rope left in a cave for long periods with extreme caution. Who knows how many falls it has taken or how much dirt is grinding around inside it. Relegate old ropes to the junk heap.

Coatings and treatments

Many attempts have been made to improve handling properties and reduce water absorption using pre-treatment processes. 'Dry' sheath treatments have little effect on water absorption although the improvement in handling is noticeable. Dry core treatments and waterproof membranes around the core certainly reduce water absorption when the rope is new but how long the treatment lasts and whether it is worth the extra cost only time will tell. The major advantage is that 'dry' treatments involve a certain amount of pre-shrinking, thus reducing long term rope shrinkage to around 5%.

Waterproof membranes seem to be especially dubious because water can leak through the tiniest hole and thereafter become trapped inside making the rope almost impossible to dry out.

Requirements for SRT rope

As you can see, rope properties interrelate and often conflict with each other. The perfect rope that maximises on all desirable properties has not yet been invented, nor is it possible to get cavers to agree on what those properties would be. The CE standard for caving rope is at least a start, even if it isn't *really* designed for caving ropes.

Choose a caving rope to suit your pocket and rigging style so long as it fits the following set of minimum requirements:

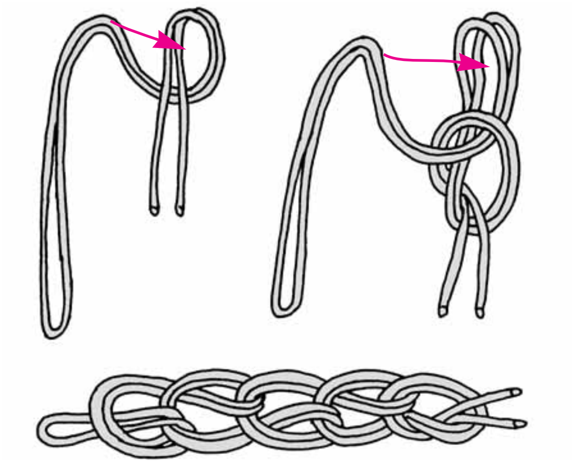
- Kernmantle construction
- Static strength in excess of 1500 kg
- Shock resistance of two or more FF1 falls
- Stretch of 1.5% to 4% with an 80 kg load
- Diameter of 7 mm to 11 mm
- Melting point in excess of 200° C

These are **minimum** requirements for a new rope and in most cases you will require more than minimum performance, primarily in the properties of abrasion and shock resistance. The only way these two properties can be significantly improved is to increase the rope diameter.

Care of ropes – new ropes

Wash or soak a new rope in water with a little detergent. This will remove the manufacturing lubricants and 'slow the rope down' so that you don't scare yourself silly on the first descent. Washing also shrinks the rope, increasing its abrasion resistance, and if you wash a rope before you use it, dirt is not trapped inside as it shrinks. If you intend to cut the rope to set lengths, make allowance for shrinkage.

Washing ropes



Chaining a rope

Washing increases the rope life and helps keep it flexible and pleasant to handle. 'Chain' the rope and wash it in the biggest washing machine you can find using non-chlorine detergent and fabric softener in the rinse. Failing this, try scrubbing brushes or 'Scotchbrites' in the creek. Even a simple rinse is better than nothing. After washing, dry ropes out of direct sunlight and store them in a dark place. If drying is not possible, wet storage causes no damage to the nylon.

Length markings

Rope length mark

You can use codes of bars and stripes to mark rope length but it is better to use a band of pale electrical tape on the rope end and mark the length with a waterproof marking pen then cover it with clear heat-shrink plastic. For simplicity you only need to write the rope length, although clubs may find that the year of purchase and some positive identification markings are also useful. Distinguish rope within a group by having each person mark their rope with identifying colours.

Rope pension plan

A well cared-for rope will appear to last for many years but the invisible loss of shock resistance could render it unsafe. Ideally two metres off the end of any rope over 5 years old should be shock tested with a FF1 test every two years and should survive **at least** one 80 kg FF1 fall. Most cavers do not go to the trouble of shock testing, they merely pension off the rope when it looks badly worn, becomes impossibly stiff, or has suffered a severe shock load.

All ropes will eventually deteriorate enough to become unsafe, however deciding exactly when to stop using a rope is often difficult. In normal use ropes tend to be cut shorter and shorter due to minor damage and rigging requirements so that eventually the pieces are so small as to be useless. Any sheath damage that causes the rope to lose its normal flex requires cutting as does any section that becomes unusually hard, soft or lumpy.

Cords

Use light accessory cord of 5 mm to 7 mm in much the same way as tape. It is cheaper than tape and adequate for most deviations.

Dyneema is a relatively new fibre made by Beal specially for caving. It comes in 5 mm white only and breaks at 1800 kg **static** load. It has exceptionally low stretch, so exceptionally low shock absorbance. It is excellent for natural anchors where once you may have used tape and risked it wearing through. Due to its poor shock absorbance it must be used so that it can never have a shock applied to it. Rig dyneema so that it is always under tension—Y belays for instance. Be especially careful rigging traverses and backup anchors with Dyneema.

For more critical uses such as belays, Dyneema is ideal. If you use light cord, use it double or triple to give adequate strength and abrasion resistance. Tie each loop separately so that if one thickness fails, the other one or two remain intact.

Table 2:6 **Cords**

Cord Diameter (mm)	Dry Weight (g/m)	Strength (kg)	Use
9	50	1800	Dynamic only for cowstails, ascender safety.
8	40	1600	Handlines, rig slings, deviations, ascender safety (prefer dynamic).
7	30	1000	Light rigging slings, deviations, footloop cords.
6	23	700	Deviations, rigging slings when doubled, footloop cords.
5.5 Kevlar	22	2000	Footloop cords, slings on climbing gear. Don't use where shock absorbency is needed.
5 Dyneema	14	1800	Footloop cords, slings on climbing gear, slings. Don't use where shock absorbency is needed.
5	15	500	Deviations, pack closures.
3	4	200	Cord Technique, pack closures.
2	2	100	Cord Technique.

Average values from manufacturers and suppliers catalogues

Table 2:7 **Tapes**

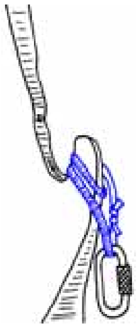
Tape Width (mm)	Dry Weight (g/m)	Strength (kg)	Use
50	50	2000	Seat harness, chest harness.
26	40	1500	Rigging, deviations, light seat harness.
20	30	1050	Light rigging, footloops, chest harness
15	20	780	Deviations, chest harness

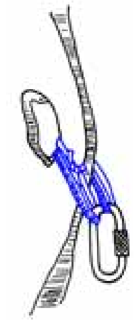
Average values from manufacturers and suppliers catalogues

Tapes

Tube or flat tape makes useful slings for anchoring to natural belays, deviations, and for step-in loops on small obstacles. Tape is especially useful on marginal natural anchors where its flat form resists rolling off the anchor. Take care with worn tape, while it is strong enough when new, it has no core as does rope, so any wear on the surface drastically affects its strength. Drop tests have shown exceptionally rapid strength losses, so never use tape under 25 mm wide in critical positions where it could be shock loaded (eg. belays, harnesses). Eight or 9 mm cord or the rope you are rigging pitches with usually makes safer slings than tape as you can easily see any sheath damage.

Anchors – natural


Bollard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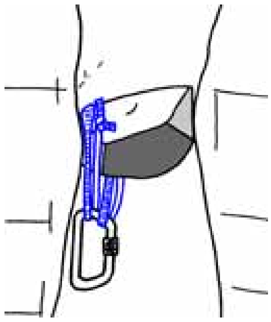
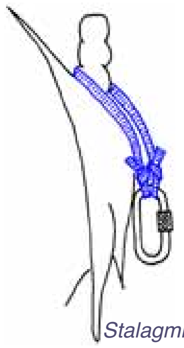
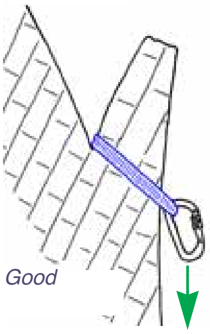
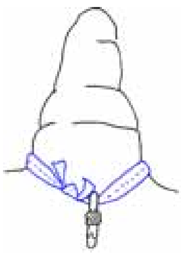
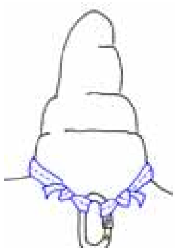
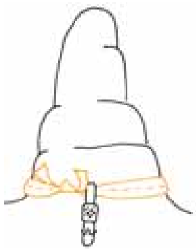

Chockstone

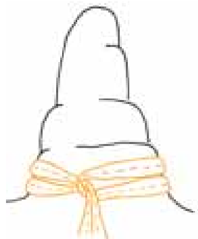

Stalagmite

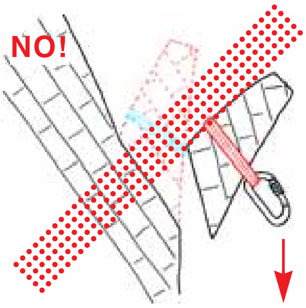

Good


Good

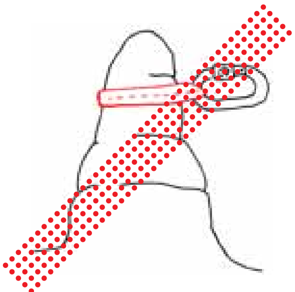

Good

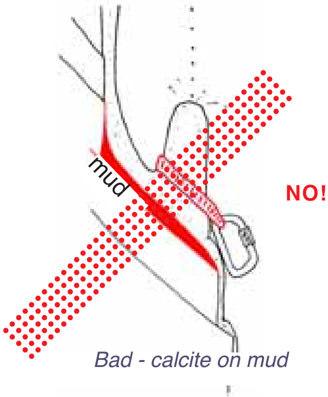

Poor-too tight


Poor-Girth hitch can overload tape



Be careful of bedding or fracture planes


Bad - Too high



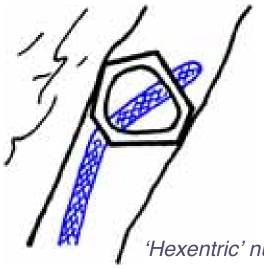
Bad - calcite on mud

Any part of the cave to which you can attach a rope is a natural anchor. This includes threads, bollards, stalagmites, stalactites, jammed boulders (chockstones) and even boulders that are just sitting there but are stable and too heavy to move.

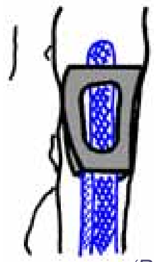
At many entrances, trees make obvious anchors and you require nothing more than common sense to choose one that is suitably tough and well anchored. If you can find a good natural anchor use it in preference to an artificial anchor as its use will cause minimal damage to the cave.

Naturals are not always as strong as they look—stalagmites can provide tempting and often adequate anchors but use them with care—their regular crystalline structure renders them surprisingly easy to snap. Always tie stalagmites as low as possible to reduce leverage. Stalagmites and flowstones can form on rotten rock or mud and there is a danger of uprooting the entire belay. Similarly bedrock is often subject to fracture along cleavage planes. You can occasionally see fractures as thin lines in clean rock or infer them by the way other rocks break. If in any doubt at all give the belay a good swift kick or tap it with a hammer. Fractured or loose rock will often give a hollow sound. The availability of good natural anchors varies greatly from cave to cave and often there will not be one where you need it.

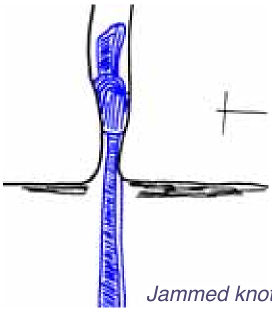
Nuts



'Hexentric' nut



'Roc' (wedge) nut



Jammed knot

The usefulness of nuts is highly dependant on the nature of the rock. When set well they can be as strong as the wire on which they are threaded but take care that they can't be lifted out sideways by a passing caver. Often a knotted tape or rope can work as well or better than a real nut. Tie a large or small knot to suit the size required and the soft nylon will often bite better than aluminium. A nylon 'nut' is not as durable as the genuine article and they are best reserved for one-off exploration use or low load applications like deviations.

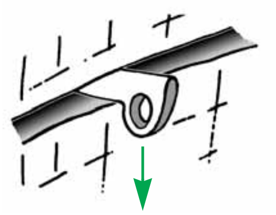
Nut placement takes some practise before it can be done safely. Always try to find a 'bombproof' placement in good rock. The wedging force exerted by a nut can be many times the load on the nut and can remove flakes and loosen jammed blocks.

Small nuts are only held in place by a tiny amount of rock as are larger nuts held by minor irregularities in a crack. In sound rock they may hold but in a cave it is not worth the risk. Take only medium sized nuts—large ones are heavy—and make sure they are well seated. In the case of both nuts and jammed knots be careful that the attachment cord does not wear through with continued use.

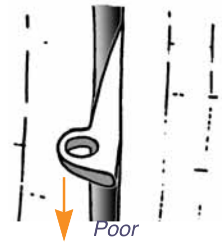
'Friends' and similar devices work well in caves but they are bulky and expensive, and the damp and dirt of caves damages them easily.

Remove jammed nuts by tapping them with a hammer. A long piton can be handy for small nuts when the hammer will not fit into the crack.

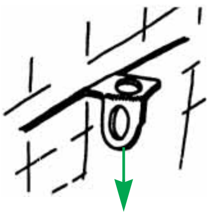
Pitons



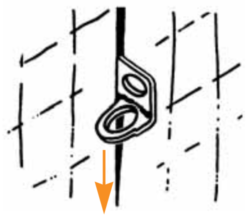
Good



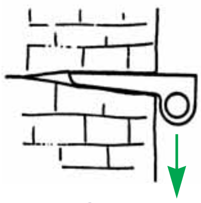
Poor



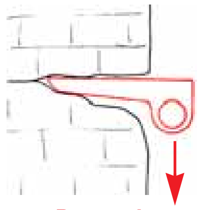
Good



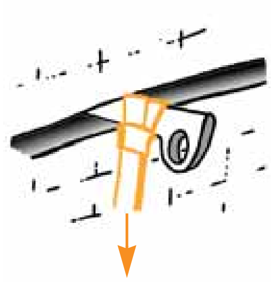
Poor



Good



Danger!



Hero loop on a long piton

Pitons can work well in some rock and it is largely a matter of luck and some experience as to whether they are useful in any particular cave. The most often used models are small to medium angles and thinner versions such as 'knifeblades' and 'lost arrows'. Pitons may be used to good effect in thinly bedded, soft or otherwise poor rock where other artificial anchors are often useless.

The security of pitons is often doubtful and even when you do find an ideal location the constant flexing caused by prusiking cavers can work them loose. Their main value comes as a fast anchor for prospecting or first descents, as easy back-up anchors (where they are not normally loaded and will not work loose) and most notably for deviations where the loads can be kept low and the consequences of failure not too severe.

Place pitons carefully. The ideal placement is one where the piton is loaded at 90° to the crack in which it is placed. eg. A horizontal crack for a downward load, a vertical crack for sideways load. Give thought to the load changing direction so that a securely placed piton does not suddenly become loaded badly if another anchor fails or as a caver passes it.

Fit the piton 1/2 to 2/3 of the way into the crack by hand then hammer it home firmly. If the eye hits before the piton is firm exchange it for a thicker version. Should the ringing sound of a piton you are hammering suddenly become dull the rock has probably fractured and you will need to try another placement.

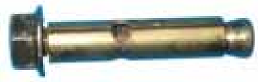
Should the tip of a piton hit the bottom of a blind crack—a common case with solution widened joints—replace it with a thicker one. The piton should grip over its entire length or at worst its outer edge. One that grips only at its tip is prone to levering out or snapping. Tie off pitons that stick out too far from the rock with a 'hero loop', a short sling tied around the shaft to reduce leverage, rather than the piton eye.

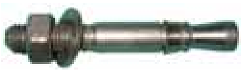
Once you've placed it, tap the head of the piton with a light sideways blow to check its security. Remove pitons by hitting them from side to side until they work loose.

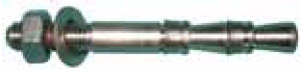
Bolts


Self drill 'Spit'

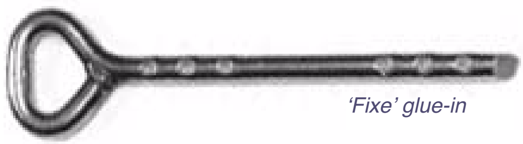

Stainless 'Spit' (not self-drilling)


Sleeve 'Dynabolt'


'Raumer' Collar stud


'Raumer' Collar stud—double expansion


'Starfix'


'Fixe' glue-in


'Fixe D' glue-in

When removable anchors are inadequate there is no choice but to cease exploration or use bolts.

Bolts give you the ability to place an anchor virtually wherever you want it. Bolts are different from other anchors in that you don't remove them from the cave after use. Whenever you place a bolt the cave is permanently damaged by you drilling a hole and smoothing an area of rock around it. For this reason alone, always place bolts with discretion.

The international standard for cave exploration is 8 mm self-drilling anchors. Anything else may be of little use to the next person and should not be placed unless long life or large diameter permanent bolts with hangers or eyebolts are used (See Fixed rigging on page 88). The exception is in the USA where imperial measurement is still standard and 3/8 inch (or very rarely 1/4 inch for artificial climbing) collar studs (parabolts) are popular. If you intend to visit an area where the bolt sizes are in doubt, check first.

Expansion stud anchors have several advantages over self-drilling anchors:

- Studs require a smaller hole than an equivalent sized self-drilling anchor—an 8 mm spit requires a 12 mm hole; an 8 mm collar stud requires an 8 mm hole; an 8 mm sleeve stud requires a 10 mm hole.
- Hole depth is not critical, it must be of the correct depth or deeper. 5 mm to 10 mm overdrilled allows for dressing of the rock surface if necessary. A little deeper than the length of the stud allows you to tap the entire anchor below the rock surface once the bolt is no longer needed—useful for climbs although it would require a new line of bolts to repeat the climb. The 'Starfix' is an exception. The hole must be the correct depth so that the anchor's eye just becomes flush with the rock as the wedge fully expands and is not a good option.
- Studs are available in long lasting, low corrosion materials such as stainless steel.
- 8 mm studs are compatible with standard bolt hangers.
- Sleeve studs may be removable if you can extract the sleeve with pliers, and therefore replaceable if damaged.
- Long sleeve studs are probably the best expansion bolts for very soft rock, but are not as good as glue-in bolts.
- 'Double expansion' studs are available for softer rock, although double collars may not help.
- Studs expand by tightening the nut rather than being hammered against the bottom of the drill hole. They will 'set' in very bad rock—although they will not necessarily hold.
- Dirty studs are easier to clean.
- Normal hangers are usable by removing the hanger's captive bolt.

Studs also have disadvantages:

- Collar studs are fine for the occasional, but high loads of rockclimbing, but for the cyclic loads of prusiking they fail relative quickly because of the bending fatigue on the thread. CNS CAF, 2001. Sleeve studs may also suffer the same problem.
- Collar studs don't expand much and are only safe in hard rock.

- In anything but hard rock, the wedge on a collar stud can pull right through the collar, or the entire stud can just pull out. They often slowly eat their way to the surface. If they require periodic tightening it's a sure sign that they're on their way out.
- Holes for studs are difficult to drill by hand, hence the need for a hammer drill. Petzl have attempted to solve this with the 'Rockpecker', a hand drill for SDS bits. Unfortunately, they require a sharp bit and can be slow.
- You must carry a power drill.
- Once your battery dies you can go no further.
- The stud hangs out of the rock and once abandoned is more visible than a spit (perhaps an advantage for finding the anchor), but it creates an eyesore unless the hole is overdrilled and the stud can be tapped below the rock surface.
- Nuts are easily lost in the cave environment and a supply of spare nuts is valuable when placing or using stud anchors.
- All threaded anchors wear out the threads with constant use.

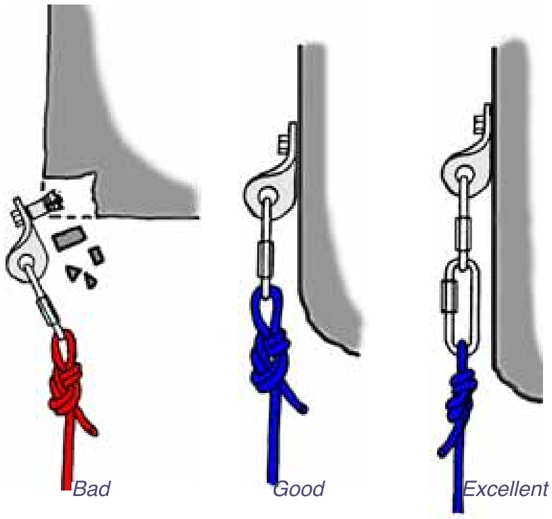
The only truly long lasting bolts are glue-in studs. They have a theoretical life of up to 200 years. They require a 12 mm dia. x 100 mm deep hole for a 10 mm stud, a lot of drilling and rock sculpting and a day or so for the glue to dry. Many UK caves have been rigged with 'P' or 'Eco' hangers much like the 'Fixe D' glue-in illustrated. An 8 mm stud requires a 14 mm hole, but have the advantage that you can replace a damaged one by drilling into the glue each side the stud, then twisting the stud out with a lever. Once you clean the hole out you can reuse it. Installation is slow and somewhat tedious. The hole must be dust and debris free and the glue mix must be correct (follow the instructions from someone like Hilti, not me!), and they're expensive. Their place is in popular caves and for fixed, heavy use rigging. See Fixed rigging on page 88.

Strength

A correctly placed spit in good rock will theoretically fail at or higher than the shear strength of the hi-tensile steel bolt - in excess of 2000 kg. Even in softer rock most anchors come adequately close to this figure. Only poorly placed bolts or those in bad rock or flowstone have given dangerously low test figures. Most testing however has been done with static rather than shock loads and there is a different failure mechanism involved due to the brittle nature of the hi-tensile steel from which the bolt and anchor are made. Obviously, larger bolts are stronger. Nevertheless it is impossible to shock load a good bolt enough to break it—the rope or cowstail is the weak link. Expansion bolts, independent of type, tend to fail catastrophically. Glue-in anchors on the other hand fail slowly. They tend to become loose but remain strong long before they fall out. In practise, bolt anchors only fail in use when they are poorly placed or in bad rock.

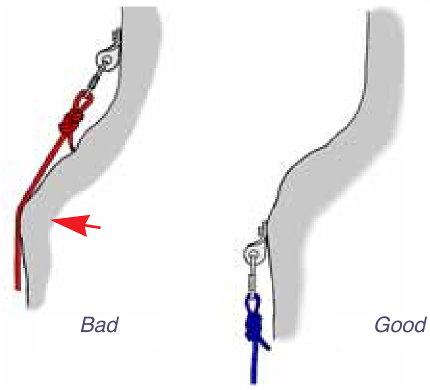
Voronia, Abkhazia

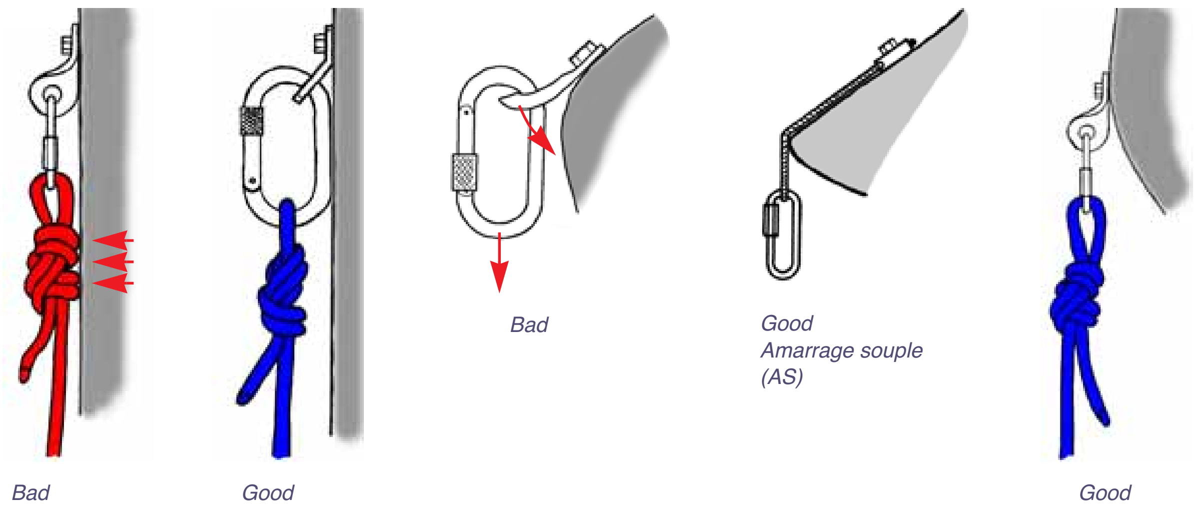
Placement



Placing a bolt is not difficult. The skill is in choosing the correct location and being able to hang there long enough to place the bolt. Once you have chosen the general location for the bolt, find a smooth, solid looking piece of rock. Try tapping around with a hammer to be sure it is really as good as it looks and makes no hollow sounds. Whenever possible avoid scoops and pockets, solution holes, cracks, calcite veins and thinly bedded rock. Prefer rounded bosses, flat areas or gentle overhangs so that the rope or knot will not grind against the rock just below the bolt.

"Instead of delicately prusiking up the rope I was powering up at full speed to avoid a total soaking when the bolt burst out of the rock above me. I was dumped back onto the ledge under the waterfall as the rope pulled tight to Stefan who was almost at the top of the pitch." — Australian Caver 120,(The bolt was in the top left 'Bad' category.)





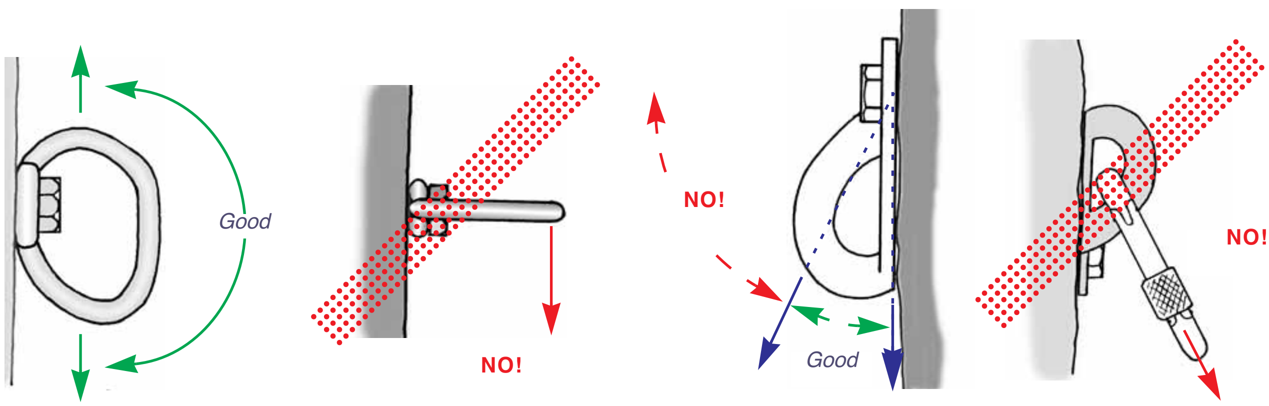
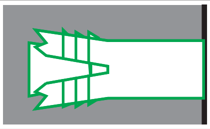
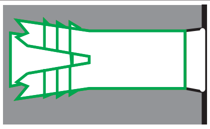
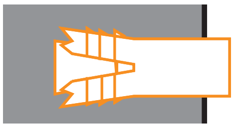
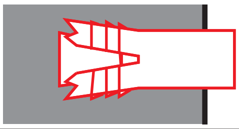
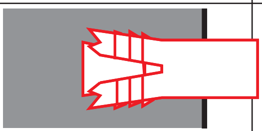
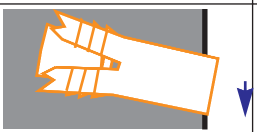
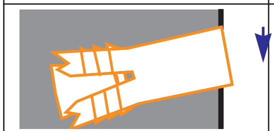
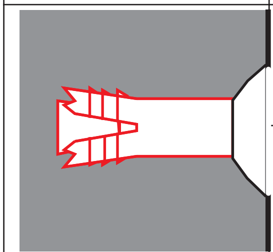
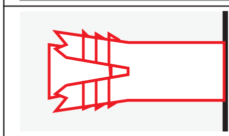
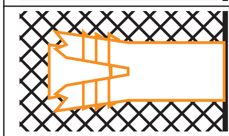


Table 2:8 **Spit strengths - placement***

Placement		Rock Quality	Failure (kg)
	ideal	hard	1400 - 2200
	2 mm below surface	hard	2200
	2 mm above surface	hard	1000
	6 mm above surface	hard	900
	12 mm above surface	hard	600
	12° positive angle	hard	1000
	12° negative angle	hard	1200
	8 mm deep crater	hard	1200
	10 mm deep crater	hard	600
	ideal	soft	700
	ideal?	flowstone	variable

* Adapted from Brindle and Smith, 1983

All tests with the load parallel to the rock.
For angled loads within the range of the hanger, strength depends on the burst strength of the rock - as good as ideal placement in hard rock.
Less than 5 mm play between the hanger and rock has very little effect on the bolt or the anchor's static strength.

Placing a Spit (self-drilling anchor)

Drill until the anchor is 2 mm to 3 mm below the surface

Smooth the surrounding rock

Wedge in, bolt ready to set

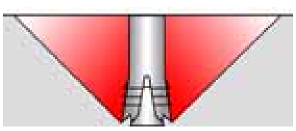
Sideways pressure can cause the rock to crack

The finished product

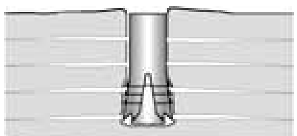
- Fully screw an anchor onto the driver, then begin the drillhole by tapping the driver lightly while rotating it clockwise until it begins to form a neat hole.
- Always keep the driver at 90° to the rock surface and be careful not to unscrew the anchor from the driver.
- Too much vigour in the early stages and sideways movement at any time may cause the hole to crater. Hard and brittle rock requires more care.
- Once you've started the hole - 4 mm to 5 mm will do - you can hit the driver a little harder.
- Hold the driver steady, give it two or three hits, then move it 1/4 of a turn, hit and so on, removing it every 10 to 15 hits to blow out all the rock dust.
- Keep drilling until the retaining nut on the driver is about to touch the rock surface, or until the top of the anchor is 2 mm to 3 mm below the edge of the hole.
- Before you set the bolt, use the drill as a chisel or the pick of the hammer to gently sculpt the surrounding rock so that the hanger will sit well and deepen the hole if necessary.
- Make sure the hole and the drill are clear of debris, place the expansion cone into the end of the drill and tap it lightly so that it will not fall out.
- Insert the assembly carefully into the hole, and still holding the driver set the bolt with firm but not violent blows until it goes in no further.
- Place a finger against the side of the driver but also touching the rock to let you feel the bolt as it moves inward. Over-hammering only risks fracturing the surrounding rock or the anchor itself.

Occasionally the driver will be stuck fast. You can remove it by tying a small sling to the driver with a Lark's Foot knot (see page 48). Put the pick of the hammer though the other end of the sling and wind it anti-clockwise around the driver until you can use the hammer as a lever.

The rim of the anchor should be level with the rock surface—a little below is fine, any distance above will weaken the anchor. The entire operation should take from 10 to 30 minutes, depending on the hardness of the rock, the awkwardness of the position and skill of the person bolting.



The stressed zone around a bolt has a radius at least as big as the anchor length



Bolts in thinly bedded rock are always suspect


Sumidero Matarocas, Chile

Cordless rotary hammers relieve much of the effort needed to place bolts by hand and replace it by the need to carry a heavy drill and battery through the cave. Depending on the cave this can be a huge time-saver or a false economy once you factor in the need to haul out and recharge the battery. Krubera- Voronia has been rigged largely with hand-driven spits simply to avoid the logistic problems. Considering the damage that bolts do to caves, the ability to place bolts relatively effortlessly has lead to an increase in their numbers and consequent damage to caves. A commensurate increase in safety will only result if the bolts are placed carefully.

Power drills also open us up to the vast array of industrial anchors available. Stud anchors allow you to drill a smaller diameter hole for the same sized bolt—an 8 mm or 10 mm hole instead of the 12 mm hole required for an 8 mm spit. Clearly this gives you more holes for your precious battery. Sleeve and collar bolts are the 'standard' here, but there are several other types also in use. So it can no longer be guaranteed that your hangers will fit the anchors in the cave. This is a very bad development for cave conservation and is leading to even worse bolt farms than before. **Make sure** that the bolt you put in will be usable by others that follow. If you remove your hanger, replace the nut, and try not to damage the stud that projects from the rock.

Placement of self-drilling anchors using a power drill is a similar procedure to hand drilling an anchor, with only minor modification:

- Use a good quality drill bit.
- Remove the drill from time to time to let the rock dust out. This allows the drill to run more freely and improves battery life.
- Drill the hole 3-5 mm short and finish the hole by hand. This is very fast because you're only flattening the bottom of the hole and not drilling much rock.
- The power drill hole has a conical bottom so the expansion cone will not be forced into the anchor far enough to set it adequately.
- Hole depth is critical, overdrilling may keep the anchor from setting correctly.

Collar and sleeve studs are very easy to place.

- Drill the correct diameter hole to the stud length or a little longer.
  Collar studs can usually tolerate a shallow hole, sleeve studs usually can't.
- Insert the stud with hanger already threaded.
- Crank it tight in the usual manner—until you feel resistance plus a 1/4 turn.
- If it just keeps tightening the rock is too soft. There's no point pulling the expansion wedge all the way to the surface. Either use it carefully, or put in another one.

Self-drilling anchors are popular because they are the lightest and most reliable method of placing bolts in caves. They are, however, not as durable as you may hope. (See Fixed rigging on page 88 & Conservation on page 154). If you use a power drill, your options are greater and you can choose the most suitable bolts for the job at hand, but in the end, you'll have to consider such things as speed of rigging, durability of the anchor, the amount of traffic the cave will take, price, availability, compatibility with other bolts in the cave and the hardness of the rock.

Bolt hangers

Plate hangers
Top row: karabiner hangs at 90˚ to the rock
Bottom row: karabiner hangs parallel to the rock

A hanger is the usual means of attaching a rope to a bolt. There is a wide variety available but by far the most popular models are those made of aluminium plate with a captive bolt at one end and an eyehole for a karabiner at the other. The bolt used is an 8 mm diameter, 16 mm long, 8.8 (hi-tensile) metric set screw with a 13 mm hexagonal head. Use stainless steel screws and hangers if the hanger will be left for some time, especially in wet conditions. Allen headed bolts are useful for anti-theft applications. The plate may be bent, twisted or made of angle stock to give a twisted effect. Plate hangers require a karabiner or a maillon rapide to attach the rope while some bent hangers specifically require an oval karabiner—the old Petzl (top centre, for example). Hangers that hang the karabiner parallel to the rock may cause the knot or loop of the rope to rub against the rock. Considerable effort has been put into designing hangers that hold the rope directly. No one has yet invented one that is entirely adequate—they may be awkward to tie the rope to, not keep the rope off the rock, difficult to clip a cowstail to, or all three! However, for back-up anchors and Y belays direct attachment hangers can work well and save some weight.

Direct attachment hangers
CAT AS old 'AS' hero loop rings
Clown
bolt and bent washer

Ring hangers come close to solving the problem. They are strong and easy to cross on rebelays but are fiddly to tie the rope to, then difficult to screw into place once you've tied the rope to them. Ring hangers also have a tendency to work loose, rotate and load themselves sideways, which can bend or break them. Their one great advantage over the other hangers is that they are excellent for overhanging bolt placements where the rope is not hanging parallel to the rock.

The CAT (Cable Amarrage TSA) has now been completely and effectively superseded by the AS (Amarrage Souple). It is exactly the same as a CAT, but uses a length of Dyneema instead of steel cable. The Dyneema can be long or short depending on the application and is easy to tie to the rope. Take care though to never risk shock loading the Dyneema. A karabiner/maillon makes them much easier to pass on a rebelay, but you can use them without as well. They are excellent for poorly placed bolts where a plate hanger sits badly. The hero loop and bent washer are most useful when abandoning a climb.

Bolt hangers are generally overstrong, breaking at 1000 kg or better and instances of them failing are very rare. The only ones that may be suspect are those made of thin, brittle stainless steel or titanium, and permanently rigged aluminium ones due to corrosion. Simple hangers are easy to make in a small workshop, although you must be careful to find a suitable aluminium alloy. As a final check, test the hanger with a severe drop tested onto a low stretch rope. Five FF1 falls would be a minimum.

The interaction between the bolt (not the anchor) and the hanger deserves some consideration. If tightened too far, the bolt head could shear off when weighted but the risk of this happening is very low for 8 mm or larger bolts. There is however a real risk of shearing the head of an 8 mm hi-tensile bolt when you are tightening it. This risk is even greater with old, corroded and 'sticky' bolts. I have never heard of or experienced the problem with stainless bolts. Some cavers use a shortened spanner so that they can never apply enough torque to a bolt to overstress it. You can also just be careful. Tighten a bolt until it stops turning easily, then tighten it no more than an extra quarter turn. At the other extreme, you must get the hanger tight enough so that it will not work loose with sideways movements of the rope. At times you will find it impossible to tighten the bolt enough to keep it from being loosened. It is then preferable to use a direct attachment hanger such as an AS. Overhanging anchor placements may also cause plate hangers to load badly and try to lever the anchor out or overload the bolt head, especially if it is over-tightened. Again it is better to use a direct attachment or ring hanger.

Rope to anchor links – maillon rapides

Apart from tying the rope directly, a maillon is the cheapest link for attaching a rope to an anchor. A 7 mm GO *(Grande Ouverture)* 'wide opening' maillon is the most suitable size. They open enough to take any rope, are of a big enough diameter so that the rope is not bent too severely through them and still allow space for a cowstail. 7 mm maillons are available in steel or, for twice the price, in aluminium. 7 mm aluminium maillons with twist hangers are easily the lightest, most versatile rope to hanger link available today. Maillons are also safe under three-way loads (unlike karabiners) and are suitable for linking the rope to traces and slings as well as to other anchors.

Karabiners

Small aluminium locking karabiners provide the easiest and fastest means of attaching a rope to an anchor. They are by far the easiest of links to cross on rebelays and are necessary to make bent bolt hangers hang properly. There are many karabiners made that are suitable for cave use and some manufacturers make a special speleo model that is oval to suit bent bolt hangers and has a mud resistant screw-gate.

Some karabiners distort so that if you lock the gate under load, it is difficult to undo once unloaded. The common result is that you are unable to remove your descender or a belay. You must reweight the karabiner in order to get it undone. Hang from the descender and loosen the karabiner gate and when derigging, loosen karabiner gates before unweighting them.

Even if you prefer maillons you'll need some non-locking karabiners for deviations and some locking karabiners for awkward belays. Strength and good handling are not especially important so the lightest, cheapest karabiners are fine. For rigging, karabiners have three major disadvantages—they are heavy, bulky and expensive.

Table 2:9 Karabiners and maillons

Type	Material	Weight (g)	Strength (kg)	Relative Cost	Use
Locking oval karabiner	aluminium	60	1600	5	General, some hangers
non-locking 'D' karabiner	aluminium	60	2000	4	Deviations, general
locking 'D' karabiner	aluminium	60	2000	5	General
mini krab	aluminium	25	550	3	Lightweight deviations
7 mm GO maillon	steel	60	2500	2	General, fixed rigging
7 mm GO maillon	aluminium	20	1000	3	Lightweight, general
6 mm maillon	steel	35	2000	1	General, Cord Technique
10 mm delta maillon	aluminium	55	1750	7	Seat maillon
10 mm half-round maillon	aluminium	55	2000	6	Seat maillon

Average values from manufacturers and suppliers catalogues

Other equipment—rope protector


Wrap-around rope protector

When prospecting using alpine technique or for IRT it is usual for the rope to touch the rock. Use a rope protector or pad to reduce the chances of the rope being cut over a sharp edge or simply to reduce wear on the rope. In many cases an empty tackle bag is sufficient, if not, there are two alternatives worth considering. The best rope protector is about 15 cm wide with velcro along the edges so that you can close it to form a tube around the rope. A poor second is a flat pad about 30 cm wide by 50 cm long with a tie-on sling at the top. Both are ideally made of a double layer of heavy canvas fabric that unfortunately absorbs water and becomes even heavier when wet. Plasticised fabrics such as PVC cave pack fabric (as illustrated) are lighter and non-absorbent. Unfortunately the heating caused by the intense contact with moving rope melts them very quickly and they stop protecting (Long, Lyon & Lyon, 2001).

Protectors made of split garden hose or similar tubing are simply not worth having. Once they bend the split works its way to the inside of the bend and opens to expose the rope in precisely the spot where a protector is needed—against the rock. If they do happen to stay in place they can cause more damage than the edge they are supposed to be protecting the rope from (Long, Lyon & Lyon, 2001). Nothing more than a heavy, bulky and potentially dangerous waste of time and effort.

Hammer

A hammer is essential for placing bolts and pitons and useful for removing the sharp edges from natural anchors and for removing tight chocks. A good caving hammer has a compact head and short pick for use in the close confines of a cave, weighs 500 g to 600 g and has a 25 cm to 30 cm long handle.

Wire trace

Traces are excellent for sharp natural belays that can eat into tape or rope very rapidly. Use traces with care as their lack of stretch makes them highly susceptible to shock failure. Take care also to not use traces unnecessarily, being much tougher than limestone they can leave ugly wire cuts in the rock. A good size is 4 mm diameter stainless cable and 1.5 m to 3 m long with an oversized eye large enough to allow a karabiner gate to pass through it swaged into each end. Never use the C clips found on the ends of most ladder traces as they are not very strong.

Dyneema is better than stainless steel cable in almost all respects.

Ladders


Wire ladder

While generally out of fashion these days, ladders still have their uses. They are particularly good on isolated small pitches where it would otherwise be necessary to rig up your abseil/prusik gear. Ladders are often easier to use than ropes in vertical squeezes and in cases where there is a small up in an otherwise down passage. They do however, quickly lose their advantage on longer pitches where a belay (and therefore a rope) is required.

Most metal equipment suffers from corrosion in the humid atmosphere of a cave and ladders should be cleaned and dried between uses. Ladders made with aluminium, stainless steel and galvanised iron do not suffer badly but those with copper parts suffer electrolysis between the cable and the rungs. This may be hard to detect but can cause catastrophic failure. Always treat ladders left in a cave for a long time with caution.

Ladders still have a role for club use. Beginners require less expertise in rigging and climbing than is necessary with rope, as well as not requiring an expensive personal descent/ascent rig. Whenever ladders are used, a belay must also be used. This may take the form of either a self-belay, or a normal belay provided the belayer is adequately trained. See Single ascender/Self belays on page 128 and Belaying on page 88.