WATCH YOUR ANCHOR!

CORROSION AND STRESS CORROSION CRACKING FAILURE OF CLIMBING ANCHORS

It is out there, lurking in the places you enjoy most, the places where you feel safest. This menace strikes in broad daylight, it cannot be seen and its attacks cannot be predicted. Those who have experienced an attack are awed and humbled. Science has a complicated explanation for it. But who will stop it?

Does this sound like a grade B horror movie? Well, this movie is playing out at popular climbing areas around the world. And the menace? It's stress corrosion cracking and corrosion.

QUICK FACTS

Recent incidents indicate unexpected failures of climbing anchors under low loads and after only some months/years in place. These failures occurring mostly on stainless (!) steel anchors are due to environmental degradation, i.e. corrosion and more specifically stress corrosion cracking (SCC).

- In worst cases, anchors can break under only a few tens of kilograms – less than the climber weight.
- Usually along sea sides but can be some kilometers away from the coast.
- Corrosion is not always visible. Could be invisible cracks.
- Stress corrosion cracking, which is the most virulent, could initiate cracks very rapidly after anchor installation. Within some weeks maybe, a few months for sure.
- All stainless steels, even the 316L grade, are concerned.
- The UIAA Safety Commission is working on finding anchors with material suitable for these environments.
- All material in place shall be considered as potentially affected.
- The most critical factors are:
    - "Moderate" relative humidity location (very dry is OK, and very humid also, in between is a problem).
    - Area NOT washed by rain (even washed by the sea can be OK!!).
    - Temperature is not critical, SCC can occur at 20°C, but higher temperatures are worse.
    - Rock types: limestone/dolomite is generally worse than sandstone or granite (Karst is the worst case).

OVERVIEW

Stress corrosion cracking (SCC) has been confirmed as the cause of a number of recent climbing anchor (bolt) failures and is further suspected in many more incidents (Table 1). Such SCC induced failures may occur within a few months or years of installation, under loads as low as body weight, in stainless steel anchors—even 316 grade steel.

Evaluating the risk due to SCC is difficult for individual climbers because SCC degradation is often not visible. Nor is SCC easy to predict as it depends on a complicated set of factors, especially: high acidity & temperature, low humidity, and unwashed, magnesium rich rock (Table 2). Small differences in microclimate can lead to SCC degradation for some bolts, while other bolts on the same climb are unaffected. SCC is associated with seaside climbing but can also occur in inland areas where corrosive elements are present, either naturally occurring in the rock itself or deposited inland by sea breezes. In response to the challenges presented by SCC degradation of climbing anchors, this document outlines management strategies for individual climbers, bolters, climbing organizations, manufacturers and the International Climbing and Mountaineering Federation (UIAA).

Table 1 Locations where stress corrosion cracking has been confirmed or is highly suspected

Thailand	Greece
Taiwan	Italy
Dominican Republic	Malta
Cayman Brac	Minorca
Hawaii	Morocco
Madagascar	Portugal
	Sardinia

Table 2 Factors contributing to stress corrosion cracking of climbing anchors

FACTORS	MOST CRITICAL ONE	remarks
ENVIRONMENTAL CHARACTERISTICS		
concentration of chloride	magnesium chloride calcium chloride sodium chloride	Chloride deposits containing salts with high solubility can be formed.
temperature	NOT any cut-off/"safe" level, but above 30°C is worse	SCC could start at 20°C, a higher temperature increase the cracking speed; the temperature of a bolt in the sun can be significantly higher than the ambient air temperature.
humidity	low relative humidity, between 20% and 70%	RH close to the deliquescence point of the chloride solution poses a significant danger of SCC.
location – coastal / wind from the sea	next to the sea up to 30 km from the coast?	There is no clear limit; winds from the sea with significant salt concentration can travel hundreds of km inland.
washed by rain or not	not washed by rain	The absence of washing allows the chloride to concentrate locally on anchors.
rock type	limestone or dolomite	Probably because of its high calcium and magnesium content.

ANCHOR CHARACTERISTICS		
stresses	high tensile stress	– from manufacturing, due to rolling, bending, cutting, drilling, and welding – from installation, due to tightening, gluing – from plastic deformation; hard falls, hammering during installation, etc – from use, due to multiple hard falls
material – which stainless steel alloy	1.4301 (304), 1.4306 (304L), or lower resistance to SCC	1.4401 (316) and 1.4404, 1.4435 (316L) are susceptible to SCC on the basis of the latest published work.

WHAT YOU SHOULD KNOW AS CLIMBER

Only destructive testing can confirm the presence/absence of SCC on installed anchors. It is not possible to visually assess or even to casually test (like to pull on them) the effective strength of the anchors in place. Even anchors that have been installed in recent months and/or look brand new could be compromised by SCC or some forms of corrosion. Tests done by a Petzl France on all bolts of an example cliff show that 20% of the installed anchors had a strength between 1 and 5 kN and thus would barely sustain body weight, let alone the mildest of fall arrests. Such conditions lead to incidents like the one that recently occurred in Sicily: during rappelling, the lower bolt of the belay broke under only the body weight of the climber (65 kg); fortunately the upper bolt held and the three climbers were unharmed.

Recommendations for climbers

When planning a trip

- Consider SCC when assessing the risk of climbing at a proposed climbing destination.
- Check with local climbers and/or climbing organizations regarding the prevalence of SCC and the corrosion resistance of local bolts.
- Be prepared for the presence of SCC, especially at hot, seaside, limestone/dolomitic destinations (Karst is the most aggressive rock).

When climbing

- Consider SCC when assessing the risk of climbing a given route.
- Belay/lower from redundant, multi-bolt anchors.
- Back up bolts and belay/rappel stances with nuts, camming devices, trees, and/or threaded hourglasses.
- Be prepared to abandon projects with suspect bolts.

In the event of bolt failure (once the climbers are safe and injuries have been attended to)

- Collect the failed anchor parts; avoid disturbing the failure surface or trying to piece together the failed anchor.
- Inform the local climbing community.
- Contact the UIAA, anchors@theuiaa.org and make the failed anchor parts available to the UIAA or one of its national federations for analysis.

WHAT YOU SHOULD KNOW WHEN INSTALLING BOLTS

- Until testing is complete and the corrosion standard is finalized, the UIAA Safety Commission recommends only Titanium grade 2 for locations that where SCC has been common.
- For areas with rare incidence of SCC or areas where SCC is suspected but not documented, anchors made from high-end High Corrosion Resistance (HCR) stainless steels may be used (MORE INFORMATION ON THESE ANCHORS AND MATERIALS WILL BE RELEASED SOON).
- 316(L) or 304(L) is NOT appropriate for any area where SCC has been documented or is suspected.
- Use of 316L grade or better alloy for corrosion resistance is recommended for all outdoor anchor components in locations where SCC has never been documented and there is no reason to suspect its presence.
- Use a calibrated torque wrench to fasten the nut in order to avoid plastic deformation of the material and to keep the axial stress at moderate levels, as suggested by the manufacturers.
- Inspect regularly, if possible every year, all the material in place.
- Please keep the UIAA informed: anchors@theuiaa.org

WHAT CLIMBING ORGANIZATIONS SHOULD KNOW

- SCC and/or corrosion and the aging of existing bolts present challenges to the climbing community that cannot be met by individual climbers.
- The main obstacles to use of SCC and/or corrosion resistant anchors are cost and availability. Individual bolters are usually short of funds, and somewhat reluctant to spend even more of their own money than they've thought was necessary from past experience. If a bolting fund provides the funds, then the bolters are almost always happy to use more resistant anchors.
- This means that the bulk of the climbing population needs to start paying for anchors, whereas in the past most had a "free ride".
- Bolting new climbs and re-bolting existing climbs to address the risks of both general corrosion and SCC will require significant investment of both time and money for the installation of new bolts that are appropriately corrosion resistant. This initial cost is offset by the increased lifespan of the resulting bolts and the decreased incidence of accident and injury.
- Quality control (QC) measures are necessary for responsible long term management of bolts, especially documentation of both anchor failures and anchor installation dates & types.
- Monitoring of bolt integrity (pull testing of off-route bolts) is similarly important. Record keeping for these QC measures must be in place for 50+ years.

The UIAA Safety Commission urges national federations and local climbing communities to plan a future that includes responsible management of bolt corrosion.

WHAT ANCHORS MANUFACTURERS SHOULD KNOW

The subject of corrosion and stress corrosion cracking can be a fairly complex and specialized subject. The UIAA has some guidelines for anchor manufacturers that will be posted on the UIAA SafeCom site. And the UIAA can help with technical advice in many cases: either from its own knowledge, or with the help of external experts. Please contact us: anchors@theuiaa.org

WHAT THE UIAA SAFETY COMMISSION IS DOING

The UIAA Safety Commission has been addressing SCC by documenting the occurrence of SCC in climbing anchors, finding consensus regarding the mechanism of SCC degradation in climbing anchors, initiating *in situ* testing of SCC resistant anchors ("off-the-shelf" products and some experimental prototypes) in the most extreme SCC/climbing environment (coastal Thailand), testing (to be carried out on "off-the-shelf" anchors), and developing a standard for the corrosion resistance of bolts. Future work includes accelerated testing of anchors to indicate whether the anchors are capable of a 50+ year SCC free lifetime. The complete anchor shall be tested in a representative concrete or stone block to replicate all stresses induced by the anchor's installation. These installation stresses in combination with the stresses resulting from the manufacturing processes (rolling, bending, machining, and perhaps welding) produce the sites where SCC can occur. Results from the accelerated tests will help refine the proposed standard and better identify which classes of anchors are appropriate for specific climbing locations. Table 3 outlines the four proposed classes of anchors and their varying degrees of resistance to environmental degradation. The objective of this work is to provide a corrosion resistance standard that will allow the climbing community to match the corrosion resistance of climbing anchors with the local environment such that bolts will not corrode significantly for 50+ years.

Table 3 Proposed UIAA anchor classes and characteristics

AN-CHOR CLASS	LOCATION	CHARACTERISTICS	POTENTIAL MATERIALS (1)	REMARKS
1	highly aggressive SCC and/or corrosive environment	**SCC in evidence:** high chloride concentration, sea salt + other salts (from karst: limestone/dolomite) & acidic environment	Titanium grade 2 & some high-end High Corrosion Resistant (HCR) steels	Although SCC is a commonly associated with seaside cliffs, it can also occur in inland locations. The wind can blow salt over 100 km inland, and beyond the reach of sea breezes the rock itself can contain the ions that promote SCC.
2	SCC and corrosive environment	**Rare SCC in evidence or suspected:** chlorides, within the critical relative humidity (RH) range where the salt crust deposited by the wind is aggressive.	most of the High Corrosion Resistant (HCR) steels	
3	outdoor environment not aggressive enough to cause SCC	**No SCC in evidence and none suspected:** some corrosion agents	AISI 316(L) and better	304 steel is not recommended any more for outdoor use!
4	indoor use, climbing gyms		no limitation with respect to corrosion	Bolts in indoor gyms in proximity to industrial areas, swimming pools, or the sea may require additional corrosion resistance.

(1) **actual anchors will be tested to confirm if they pass**