CORROSION AND STRESS CORROSION CRACKING FAILURE OF CLIMBING ANCHORS

UIAA 123 standard update, 2020

‘一般腐蝕’及‘應力腐蝕’之攀岩錨栓斷裂

國際山岳聯盟「攀岩錨栓安全規範（UIAA 123）」更新公告, 2020

The UIAA Safety Commission is composed of national federation delegates, manufacturers and accredited testing laboratories.

The subject of corrosion and stress corrosion cracking failure has been a work in progress for the last ten years within SafeCom. December 2020, the Commission is able to release the resultsand update itsStandard UIAA 123Rock Anchors V4_2020 . This major update is based on scientific research performed by Brest (France) and Prague(Czech Republic) laboratories, coordinated and funded by the UIAA, for the safety of all climbers worldwide.

This Standard has been updated based on SafeCom's best knowledge of atmospherically induced stress corrosion cracking, i.e. with respect mainly to chloride resistance. Nevertheless, in some locations and environments this is not the appropriate procedure and where additional tests need to be performed, e.g. under high sulphate content. Further research is ongoing to gain a clearer understanding of this phenomena and how to determine which locations are concerned.

UIAA 安全委員會由會員（國家級山岳聯盟）代表、製造商、和經由 UIAA 認可的實驗室組成。

過去十年來，UIAA 安全委員會一直都在進行一般腐蝕以及應力腐蝕研究。2020 年 12 月，安全委員會終能公佈研究結果並更新「UIAA123 攀岩錨栓 V4_2020」規範。此更新主要是基於 UIAA 主持並資助的布雷斯特（法國）和布拉格（捷克共和國）的實驗室科學研究，以確保全球登山者以及攀岩者的安全。

此次更新是根據 UIAA 安全委員會針對 ‘環境引發應力腐蝕’ ，亦即針對氯化物為腐蝕原因之最佳知識所定。但，在一些地區或特定環境，氯化物並不是唯一原因，例如在含高硫酸鹽的環境也可能發生應力腐蝕，關於後者，有關測試以及研究是必要的，也正在進行，以更清楚了解環境引發應力腐蝕的原因並用以判斷可能發生的區域。

Reminder of the quick facts

重點事實回顧

Recent incidents indicate unexpected failures of climbing anchors after beingset-in place for a few months/years and under low loads. These failures occur mostly on stainless steel anchors due to environmental degradation, i.e. corrosion and more specifically stress corrosion cracking (SCC).

- In worst cases, anchors can break under the weight of ten to twenty kilograms –obviously less than the averageclimber's weight.
- Usually in coastal locations, but even up to a few kilometres away from the coast.
- All material in warm coastal areas shall be considered as potentially affected
- Corrosion is not always visible and can occur in cracks not seen by visual inspection.
- Stress corrosion cracking is the most virulent and canvery rapidly initiate cracks shortlyafter anchor installation. In some cases, within a few months and almost certainly within a few years.
- All metallic anchors, including parts made of stainless steel or aluminium alloys are impacted, except those which are rated UIAA 123-SCC.

The most critical factors are:

  - "Moderate" relative humidity locations.*(The very dry and very humid locations are OK,it is the in-between the two extremes that is a problem)*
  - Areas NOT being washed clean by a rainfall*(even being washed by the sea can be OK!).*
  - Temperature: SCC can occur at 20°C, higher temperatures are worse.

最近發生的事件顯示，攀岩錨栓安裝後，區區幾個月或幾年即可能出乎意料的斷裂、失效。失效的錨栓多為不鏽鋼製，而失效原因均為環境因素所引發之應力腐蝕（SCC）。

- 最壞的情況，錨栓可在遠低於登山攀岩者平均體重的 10 至 20 公斤荷重下折斷。
- 通常發生在沿海地區，但離海岸數公里之處亦有可能發生。
- 在暖和沿海地區，所有材料都應視為有腐蝕潛在疑慮。
- 腐蝕不一定能以目視來判斷，尤其發生在肉眼看不到的裂紋腐蝕。
- 其中應力腐蝕（SCC）最危險，可在安裝錨栓後不久迅速引發，在某些情況下，幾個月內即可能發生，至多幾年即會引發。

- 除 UIAA 123-SCC 等級認證的金屬錨栓外，所有金屬錨栓，包括任何不銹鋼或鋁合金零件，均可能引發應力腐蝕。

關鍵因素：

  - 常發生於“中等”相對濕度區域（*非常乾燥和非常潮濕的區域都算安全，處於這兩個極端之間的地區反而有潛在危險*）
  - 不能常被雨水沖洗的區域（*即使被海水沖洗也可以！*）。
  - 溫度：應力腐蝕可在 20°C 時發生，溫度愈高可能性愈高。

What are the main changes?

規範主要更新事項

- The list of acceptable materials for the most corrosion resistant class have been removed.
- The new Standard now tests the complete anchor to ensure as much as possible the stresses it may endure upon installation.
- The highest corrosion resistance classis Stress Corrosion Cracking (SCC)
- The UIAA Safety Label certificate is given to anchors that have successfully passed the general corrosion and Stress Corrosion Cracking (SCC) tests as per Table 1.

- 刪除舊擬之耐腐蝕等級材料清單。
- 新標準將測試安置完全之錨栓，以確保安裝產生之應力也涵蓋於測試條件中。
- 新標準最高的耐腐蝕等級為耐應力腐蝕（SCC）
- UIAA 安全認證將授予通過一般腐蝕和應力腐蝕相關測試之錨栓，請見表（1）。

Why testing the complete anchor?

為何測試安置完全之錨栓？

Influential factors: amount of internal Stress and resistance to SCC

- the manufacturing method: bending, welding, cutting, drilling, even laser engraving adds a significant amount of internal stresses.
- the installation: expansion anchors are subject to additional stress when screwed in place. Hammering with any metallic tool is also very detrimental and should be avoided.

This is why during testing the screw-in anchors are installed in a granite block as per manufacturer's instructions for use and installation. For glue-in anchors (*it is considered that the glue does not induce significant stress),* they are fully immersed in the solution.

主要考量：內應力以及抗應力腐蝕能力

- 製程因素：任何錨栓製程之撓曲、焊接、切割、鑽孔、甚至雷射雕刻都會產生相當內應力。
- 安裝因素：安裝膨脹錨栓會產生額外應力，用任何金屬工具錘打也對錨栓有害，應避免。

所以測試過程中，所有必須施力旋入之錨栓，須按照製造商之安裝說明安置在花崗岩塊中測試，而膠固式錨栓（*目前認為膠固的方式不會產生顯著的應力*），則必須整體浸入溶液中測試。

Why three classes?

為何分 3 等級？

The lastest research reveals that defining classes by only the material type is not pertinent since some anchors made of low SCC resistant alloys (e.g. 316L) could pass the test while other anchors made of high-end SCC resistant material do not pass the same test. This is mainly because the stress on the anchors from different manufactures could vary.

For these reasons, it has been decided to have three classes, and only one of them with resistance to SCC.

最新研究顯示，用材料種類來定義抗腐蝕等級並不適合，因為某些抗應力腐蝕能力低的合金所製錨栓（例如 316L）可通過測試，而某些抗應力腐蝕能力高的材料所製錨栓卻通不過相同測試，究因爲不同廠商之製程造成的內應力不同。

源此，決定分為三等級，其中只有一個等級具抗應力腐蝕能力。

Table 1: UIAA 123 Rock Anchor V4_2020Classes and Environment Characteristics

表（1）：國際山岳聯盟'攀岩錨栓安全規範'第四版 2020（UIAA 123 RockAnchor V4_2020）等級區分和環境因素

UIAA 123 Class 等級	Signification 說明	SCC resistance 抗應力腐蝕能力	General corrosion resistance 抗一般腐蝕能力	Characteristics of environment 適用區域，其環境因素和特徵	Important considerations 其它重要考量
SCC	High SCC and General Corrosion Resistance 應力腐蝕以及一般腐蝕抗拒能力都強	**High** **高**	**High** **高**	**SCC in evidence, for example (but not only):** high chloride concentration, temperature above 30°C, humidity between 20% to 70%, sea salt and/or other chloride salts, and/or acidic environment. **該區曾發生應力腐蝕（但此非唯一考量）：** 高濃度氯化物易集中區， 該區溫度常高於 30°C， 該區相對濕度常介於 20%和 70%之間， 易產生海鹽或氯化物鹽類，且環境化學性質偏酸之區域。	Although SCC is commonly associated with seaside cliffs, it can also occur inland and in other locations, e.g. indoor swimming pools. 縱使應力腐蝕常發生於海邊，但內陸區也會發生，也會發生於室內游泳池。
GC	General Corrosion Resistance 一般腐蝕抗拒能力強	**NO** **(unspecified)** 未界定	**High** 高	**No SCC in evidence and none suspected,** some corrosion agents. **未曾發生過應力腐蝕，** **環境因素不易引發應力腐蝕，** 存有一些一般腐蝕因素。	
LC	Low Corrosion Resistance 一般腐蝕抗拒能力低	**NO** **(unspecified)** 未界定	**Medium** **中**	**No SCC in evidence and none suspected.** **未曾發生過應力腐蝕，** **環境因素不易引發應力腐蝕。**	Rock anchors in indoor gyms and in proximity to industrial areas, swimming pools, or the sea may require use of class SCC anchor. 若室內岩場接近工業區、游泳池、或海邊，可能需使用 SCC 級錨栓。

What is Stress Corrosion Cracking?

何謂應力腐蝕？

Stress Corrosion Cracking (SCC) is a very virulent type of corrosion that could provoke cracks very rapidly. Contrary to general corrosion, which generates sufficient amounts of well visible corrosion products such as rust, SCC can usually not be detected during on-site visual inspection. Many stainless steels, aluminium alloys and other metallic materials are affected.

SCC is influenced by many different factors, as presented in Table 2.

應力腐蝕是一種非常危險的腐蝕，可迅速引發金屬內部產生裂隙。與一般腐蝕不同，後者會產生足以用肉眼就可以察覺到的外部鏽蝕；但應力腐蝕即使發生，外表也不易察覺。許多不銹鋼、鋁合金和其它金屬材料都可能引發應力腐蝕。

可能引發應力腐蝕因素簡列如表（２）：

Table 2: Factors contributing to stress corrosion cracking of climbing anchors

表（２）：應力腐蝕誘發因素

FACTORS 原因	MOST CRITICAL ONE 重要因素	Remarks 備註
ENVIRONMENTAL CHARACTERISTICS **環境因素**		
concentration of chloride 高濃度氯化物	magnesiumchloride, calciumchloride, seasalt 氯化鎂 氯化鈣 海鹽	Chloride deposits containing salts with high solubility can be formed. 尤其是氯化物沉積處含有易潮解鹽份之區域
Temperature 溫度	NOT any cut-off/"safe" level, but above 30°C is worse 無一定"安全臨界值"，但 30°C 以上易引發	SCC could start at 20°C, a higher temperature increases the cracking speed; the temperature of a bolt in the sun can be significantly higher than the ambient air temperature. 應力腐蝕可在 20°C 引發，高溫則加快金屬內部裂隙蔓延速度；暴露在陽光下時，錨栓溫度往往比現場氣溫高出許多。
Humidity 濕度	low relative humidity, between 20% and 70% 相對濕度介於 20%與 70%	RH close to the deliquescence point of the chloride solution poses a significant danger of SCC. Localized RH of the anchor can be significantly different from ambient RH, e.g. when exposed to the sun. 相對濕度趨近氯化物潮解點之區域易引發應力腐蝕。局部相對濕度（例如陽光照射下的錨栓附近相對濕度），可能會與當地環境的相對濕度有顯著的不同。
location – coastal / wind from the sea 靠海或海風所及之地	next to the sea up to typically 30 km from the coast 離海 30 公里之內	**There is no clear limit;** winds from the sea with significant salt concentration can travel far inland. **但無一定界線**，挾帶大量鹽分的海風可吹至更深內陸

washed by rain or not 雨量	not washed by rain 雨量少之區域	The absence of washing allows the chloride to concentrate locally on anchors. 缺乏雨水沖洗，氯化物更容易累積在錨栓上
rock type 岩石種類	Unspecified, all rock types could be affected 未界定，應力腐蝕可發生在任何種類岩石上	Some rock types can make conditions worse than others, depending on specific circumstances. 在特定的狀況下，有些種類的岩石比其它岩石易發生應力腐蝕
ANCHOR CHARACTERISTICS **錨栓因素**		
Stresses 應力	high tensile stress 高拉/張應力	– **from manufacturing**, due to rolling, bending, cutting, drilling, and welding – **from installation**, due e.g. to tightening, hammering – **from plastic deformation**;e.g. multiple hard falls -**來自製程**，譬如滾軋、撓曲、切割、鑽孔、焊接等 - **來自安裝**，譬如鎖緊、敲打等 - **來自塑形變形**，譬如承受多次嚴重墜落

Which locations are affected?

哪些區域容易發生應力腐蝕？

Potentially all coastal areas could be affected by atmospheric induced stress corrosion cracking, including up to several kilometres from the coast.To this day, it is still not possible to clearly distinguish affected locations from safe ones. The variation of many parameters as presented in Table 2 can influence the corrosion conditions. For example, the wind can blow salt over hundreds of kms inland, and beyond the reach of sea breezes the rock itself can contain the ions that promote SCC.

The UIAA has created a Map of known corrosion locations. This map is intended only as a reference to identify areas where examples of corrosion have been logged. It is designed only as an informative guide based on data received and assessed. **It is not intended as a complete reference and is subject to changes beyond the UIAA's control.**

To support the UIAA Safety Commission with its analysis and to help add more areas to the map thereby improving the information available to climbers about dangerous or potentially dangerous areas to climb, a dedicated form is available to share information about corrosion or failed anchors.

沿海地區，包括離海岸數公里的區域，都可能被‘環境引發應力腐蝕’所影響。迄今，仍無法清楚界定會受影響或安全的界線。如表（2）所示，許多因素都有變數，譬如，風可能挾帶海鹽至內陸數百公里處，即使海風不能及，岩石本身也可能含有可促發應力腐蝕的電離子。

UIAA 建立了已知應力腐蝕發生區域的地圖，但該地圖僅供參考，目的是記錄應力腐蝕實發地區。**該地圖是接收各方資訊並評估最新訊息而設計的參考指南，所以該地圖內容並不是由 UIAA 所掌控的，也不是完整資料，內容隨時可能更改。**

為了支持 UIAA 安全委員會這方面的分析，並協助地圖上的訊息更完整，從而改善攀岩者可能面對的危險或潛在危險，請使用此專用表格，共享有關錨栓腐蝕或失效的資訊。

What you should know when installing bolts

安裝錨栓應注意事項

- **Use only UIAA123 – *SCC* class certified anchors. This class for locations where SCC is common. In case of doubt and for areas with rare incidence of SCC or areas where SCC is suspected but not documented always choose the highest class.**
- **Do not combine bolts, nuts, washers or hangers of dissimilar metals**, because galvanic corrosion could be initiated due to the different electrochemical potentials.
- **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.
- If possible, **regularly inspect the material(s) in place.**
- **If corroded anchors are found, contact the UIAA.Failed anchor parts can be sent to to the UIAA or one of its national federations for analysis:** https://theuiaa.typeform.com/to/rlBZyc

- **在應力腐蝕發生過地區或應力腐蝕發生率低但懷疑可能會發生地區，請使用 UIAA123 – SCC 認證的錨栓。**
- **勿組合不同金屬（或不同等級金屬）的螺栓，螺母，墊圈或耳片**，因為不同類別金屬接觸所造成之電化電位差將導致電流腐蝕。
- 安裝膨脹式錨栓時，應按照製造商使用說明，並使用可校準扳手扭緊錨栓，以避免材料發生塑性變形並保持適當軸向應力。
- 盡可能**定期檢查錨栓。**
- **如果發現鏽蝕的錨栓，請跟 UIAA 聯絡，失效錨栓可送至 UIAA 或在地國之 UIAA 會員組織進行分析：https://theuiaa.typeform.com/to/rlBZyc**

How to check when climbing?

如何檢視錨栓？

The UIAA123 V4_2020 Standard states that the anchors shall be marked with the letters *UIAA* followed by the class *SCC, GC* or *LC* as per Table 1.

Evaluating the risk due to SCC is almost impossible for individual climbers because SCC degradation is often not visible. Only destructive testing can confirm the presence/absence of SCC on installed anchors. Even anchors that have been installed in recent months and/or look brand new could be compromised by SCC or some forms of corrosion.

SCC is very difficult to predict as it depends on a complicated set of factors, especiallyelevated temperature, low humidity, and formation of magnesium -or calcium- rich chloride deposits at unwashed locations (Table2). 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.

所有通過 UIAA123 V4_2020 規範錨栓，均有「*UIAA*」標示，以及表（1）所示「*SCC*」，「*GC*」、或「*LC*」等字樣。

個人幾乎不太可能評估錨栓是否已發生應力腐蝕，因為應力腐蝕外表通常不可見，只有破壞性測試才能確認。即使安裝僅幾個月或看起來很新的錨栓，也可能發生應力腐蝕或其它形式腐蝕。

應力腐蝕很難預測，因為它取決於一些複雜因素，尤其是高溫、低濕度、以及鎂或鈣的氯化沉積物不易清洗之處（見表 2）。局部環境的微小差異會導致某條路線上一些錨栓感染到應力腐蝕，但其它錨栓卻不受影響。應力腐蝕固然與海邊有關，但也可能發生在內陸，只要該區的岩石本身具有腐蝕因素，或海風能帶進腐蝕因素在該地累積。

Recommendations for climbers

給登山、攀岩者的建議

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 destinations.

When climbing

- Consider SCC when assessing the risk of climbing a given route.
- Belay/lower from redundant, multi-bolt anchors.
- When in doubt, accept the need to back up bolts and belay/rappel stances with nuts, camming devices, trees, and/or threaded hour glasses.
- 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. Faulty/failed anchor parts can be sent to the UIAA or one of its national federations for analysis:** https://theuiaa.typeform.com/to/rlBZyc

攀登前規劃

- 把目的地是否發生過應力腐蝕納入風險考量。
- 與當地的登山攀岩者或登山攀岩組織聯繫，了解該地錨栓應力腐蝕發生可能性以及其它耐腐蝕性。
- 為應力腐蝕做好準備，尤其目的地是炎熱沿海地區。

攀登時

- 評估既定路線風險時，應納入應力腐蝕可能性考量。
- 確保/下放時，使用多錨栓系統。
- 如對錨栓不放心，使用岩楔或自然物做出備份系統。
- 如對使用的**錨**栓不放心，從路線上撤退

萬一錨栓失效（在登山者已然安全並受到照顧前提下）

- 收集失效的錨栓，避免損及破壞處或試圖將破壞的零件重新組合。
- 通知當地的攀岩社群。
- **與 UIAA 聯絡，失效錨栓可送至 UIAA 或在地國之 UIAA 會員組織進行分析** https://theuiaa.typeform.com/to/rlBZyc

What climbing organizations should know

登山攀岩組織應知

- 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 can be short of funds, and somewhat reluctant to spend even more of their own money.When a bolting fund is available to provide funding,the bolters are always happy to use the more resistant anchors.
- This means that the bulk of the climbing population needs to start paying more for anchors, whereas in the past most climbers 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.

- 應力/其它腐蝕以及老舊錨栓對整體登山攀岩社群的挑戰，個人無法應對。
- 使用抗應力腐蝕/抗其它腐蝕錨栓的主要障礙是成本和可得性。錨栓工作者普遍缺乏資金，但當有錨栓資金可用時，錨栓工作者總是樂意使用抗腐蝕性更高的錨栓。
- 這意味著絕大部分的登山攀岩社群要準備為錨栓支付更多的費用，而在過去，大多數攀登者都享受無本的‘搭便車’。
- 這也意味為了解決應力腐蝕以及一般腐蝕的問題，大量的時間和資金是必須的，以便安裝具有適當耐腐蝕的新錨栓，但這初始成本將被延長的錨栓壽命和減少事故和傷害的長期效益所抵消。
- 有效的地方性長期錨栓品質管控（QC）是必要的，尤其是建立錨栓失效、安裝日期、和錨栓類型有關檔案。
- 錨栓品質監控（例如拉拔測試）同樣重要，以上這些錨栓品管記錄必須保持 50 年以上。

The UIAA Safety Commission urges national federations and local climbing communities to plan a future that includes responsible management of bolt corrosion and that asks for UIAA123 v4 certified products.

UIAA 安全委員會期許各國會員和各在地攀岩社群妥善計劃更好的未來，包括進行有效的錨栓腐蝕管理並使用 UIAA 123 v4 認證產品。

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