The use of self-tapping concrete screws in Volcanic rock

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When people talk about volcanic caves, most tend to think of lava tubes — horizontal, easy-to-explore tunnels formed by flowing lava. What usually doesn't come to mind are shafts, lava falls, deep dolines, and volcanic craters. In these cases, cave exploration often involves vertical access, requiring rope techniques and ……the use of rock anchors.

Unlike limestone, volcanic rock is generally not homogeneous in structure. Lava flows typically consist of many different layers welded together, each representing the varying consistency of lava material emitted by the volcano at different times. Some layers are thin; one may be as hard as glass on the outside, while the interior contains only soft ash or welded clasts. In other cases, the lava is solid and hard all the way down but full of cracks — as is often the case with ʻAʻā lava. Or, the lava may be full of air- and gas bubbles, forming rock that is hard on the outside but full of cavities inside, which is typically the case with pāhoehoe lava.

This means that, unlike most limestones, volcanic rock has a highly inconsistent structure — its quality can vary every 10 centimeters. This variability forms the basis for the challenges faced when installing self tapping screw anchors for descending into volcanic shafts.

In practice, conditions are often demanding, and cavers continually push the limits — as they do, for example, in some parts of the Canary Islands. Many volcanic shaft caves can be found there: some are fumaroles, others are remnants of magma chambers, and some are simply pressure-release vents from lava conduits.

In several vertical caves, you can find empty drill holes at locations where anchors would normally be expected above the shafts. These holes are intended for re-use when installing self-tapping screw anchors, which are typically 8 mm in diameter.

How safe this practice actually is — or isn't — is the question we aim to address in this article. Several investigations and publications have already explored this topic in the past, notably in 2018 and 2019. See: https://cncc.org.uk/file/3aa51cae-4851-c59a-1f42-93e366425a6e from Simon Wilson, a translated publication in Stalactite 68 2019 by Rolf Siegenthaler (SGH Bern), and Florian Hof (SCVJ) http://bergimpuls.ch/assets/files/Betonschrauben-E.pdf and https://cncc.org.uk/file/a8a27a96-d649-f6a2-a9b4-2c402f60b8c1 with " the title Concrete screws – testing for caving use" from Ian Walker, 02/04/2024.

The 2 first mentioned investigations were carried out in limestone and, in both reports, the authors strongly recommended that this type of anchor be used only by adequately experienced cavers — and for exploration only!

However, neither report investigated the re-use of existing drill holes with different brands or models of screw anchors. Nor did they address the use of these anchors in rock types other than limestone. Therefore, the safety of using self-tapping screw anchors — and especially the re-use of pre-drilled holes — in volcanic rock remains an open question.

Volcanic cavers in the past always have been aware of the challenges associated while installing anchors in volcanic rock. Traditionally, expansion anchors have been the most commonly used type in this setting. These anchors work under tension, and their reliability can be assessed by checking whether a specific tightening torque is achieved.

In more recent years, chemically bonded anchors have become increasingly popular. When made of stainless steel, they can offer long-term durability. However, even these are not immune to the harsh conditions often found in volcanic environments, where wear, corrosion, and mechanical stress can significantly reduce anchor lifespan..

Most of the problems associated with anchors on the short and long term in Volcanic rock are:

- Aggressive volcanic cave environments caused by minerals such as salts, sulfur, and chlorides.
- Inconsistent composition of the rock with mixing layers of soft and hard material, welded clasts, and ash particles (e.g., glassy outer crusts with softer interiors).
- Air-filled rock, ranging from fine porous textures to larger hidden cavities not visible from the outside
- Cracks resulting from the lava's cooling process, as well as pressure fractures, tectonic cracks, fissures caused by vibration, shifting of layers, or earthquakes.

In this study, we re-consider the safe use of self-tapping screw anchors, which have become widely adopted in the caving community over the past decade and are now being introduced into volcanic environments.

The main question of our investigation is whether these self-tapping concrete screws are suitable for use in volcanic rock — and, furthermore, whether pre-drilled holes can be safely re-used, as is currently practiced in some regions of Spain.

To our knowledge, the most commonly used self-tapping screw anchors are the Fischer FBS II US 8 × 70 and the Heco Multi-Monti (MS) 10 × 60.

Figure 1: examples of the Fischer and Heco self-tapping screw anchors.

Both models require an 8 mm drill hole. Fischer calls its model by the drill-hole diameter (8), whereas Heco labels its product according to the diameter of the anchor rod (10) — which can be somewhat confusing.

The choice to use one type of anchor with a 70 mm shaft and the other with a 60 mm shaft was based primarily on product availability at the time of testing. Additionally, Fischer does not offer a 60 mm version of this self-tapping screw anchor with a hexagonal head

Some facts:
Both anchors require the drill hole to be at least 10 mm deeper than the length of the anchor shaft. After drilling, the holes must be cleaned of dust, (cleaning with air). The rock surface where the anchor is placed must have a consistent composition , being suitable and hard (strong) enough to support this type of anchor; and…. Installation should only be carried out by experienced cavers who have the necessary skills to assess and judge whether the surface is suitable for installing a self-tapping screw anchor — by observation, feel, and understanding the characteristics of this specific rock.

In next list the measured dimensions are presented of several randomly selected self-tapping screw anchors used in this study. (figure 2 dimensions of the tested self-tapping screw anchors: Heco MMS 10 x 60 and Fischer FBSII US 8 x 70)

	Heco MMS 10 x 60	Fischer FBSII US 8 x 70
diam. Internal tapered in mm.*	7,34 - 7,5	7,5 – 7,5
diam. external tapered in mm.*	9,6 -10,3	9,7- 10,1
amount of serrated first thread pitches	4	2,5
amount of thread pitches per 60mm.	10	8
distance of thread pitches in mm.	6,15	8,10
* all dimensions are measured on a random chosen screws and can differentiate tenth of milometers within one production batch		

Figure 2a : dimensions of the tested self-tapping screw anchors

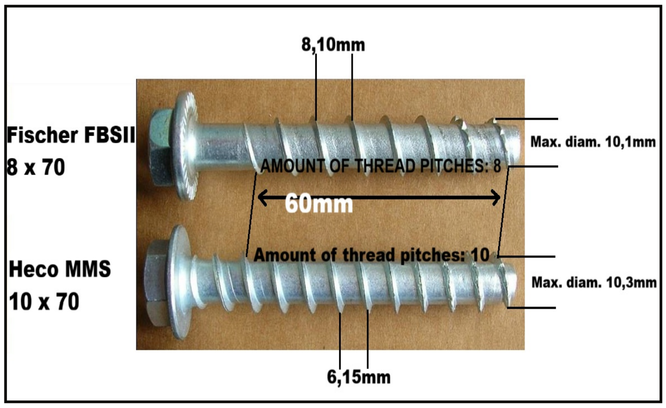


Figure 2b: Fischer FBSII 8 x 70 anchor and Heco MMS 10 x 70 anchor

As can be seen in Figure 2a and 2b, the dimensions of these examples of commonly used anchor brands vary significantly. Although size differences of only a few tenths of a millimeter may occur even within the same production batch, the overall observation is that the Fischer FBS II 8 × 70 and the Heco MMS 10 × 70 have no identical dimensions at all. Even the hexagonal heads differ: the Fischer requires a 13 mm spanner, while the Heco needs a 17 mm spanner. The thread geometry also varies — Fischer has 8 thread pitches over a distance of 60 mm , whereas Heco has 10 pitches over the same length. In addition, both the inner and outer thread diameters differ slightly. Although these differences are only in the order of tenths of a millimeter, such variations are significant in the context of steel threading and can directly influence compatibility and performance.

The testing:
Our testing ground for the anchors was Lanzarote, one of the eight Canary Islands. The island offers a wide range of volcanic rock types — plus good food and constant sunshine. It also features numerous vertical caves, and on top of that reliable anchoring systems could be highly valuable for the many barrancos (canyons) found on the island, some of which reach depths of over 400 meters.

Because of the great diversity of types of lava present on Lanzarote, we were able to test the reliability of anchors in various environments. The goal was not to cover all types of volcanic rock worldwide, but rather to provide additional insight and raise awareness among cavers about the potential false sense of security when using this type of anchors in volcanic rock.

To simulate real-life conditions, we selected several test locations on abandoned lava fields where multiple types of lava rock can be found equal to the volcanic rock near to caves.

In line with the European standard EN 795 we conducted axial pull-out tests. While this axial directed testing method not fully represents the actual load direction typically experienced by anchors in practice (which is usually shear loading), it is accepted in standardization protocols as an appropriate method to evaluate the installation soundness of fall-arrest anchors. The columns in Figure 3 show the results of the many pull-out tests that were conducted.

		TESTING SCREW ANCHORS: Fischer FBSII US 8 x 70 and Heco MMS 10 x 60 : drillhole 8mm.							
1		A	TEST B	TEST C	TEST D	Additional TEST E, Failure test			
Type of anchor		Type of volcanic rock	1 x Use test, 6Kn.	2x Re-use same drill hole/ same anchor as in column 1. 6KN test. **	Re-use same drill hole with FBS anchor + successive MMS 10 x 60 anchor. 6Kn. Test **		OK? Y/N	Remarks	Location
									LANZAROTE
Fischer FBSII US 8 x 70	1	black basalt rock	OK	OK	6Kn. 1x test FBS + 1 x test MMS	MMS Pulls out at 8Kn.	Y	After Test D Bolt is moving back and forth	C Carmelo
Fischer FBSII US 8 x 70	2	slab-crusted flow lava	Failure 4kn.	xxx	xxx	xxx	N	FBS anchor pulls out slab	C. Carmelo
Fischer FBSII US 8 x 70	3	On top of Pahoehoe lava	Failure 1kn	xxx	xxx	xxx	N	Test B results in cracks and pull out at 1kn	C. Naturalistas
Fischer FBSII US 8 x 70	4	On top of Pahoehoe lava	OK	Failure	FBS-test OK. MMS-test Failure. MMS causes stripped drill hole, cannot be fastened	xxx	N	Test C: after 2 x pulltest FBS moves 3mm. Outwards.	C. Naturalistas
Heco MMS 10 x 60	5	On top of Pahoehoe lava	OK comes out 1mm	OK, MMS is moving back and forth	MMS test OK. FBS-test OK (bolt comes out 4mm)	xxx	Y/N	Dubious results. Holes cannot be re-used!	C. Naturalistas
Fischer FBSII US 8 x 70	6	On top of Pahoehoe lava	OK comes out 2mm.	OK, comes out 5mm.	MMS-test Failure. MMS causes stripped drill hole, cannot be fastened	xxx	N		C. Naturalistas
Fischer FBSII US 8 x 70	7	at side of Pahoehoe layer	OK	Before use: cleaning hole by air. Failure 5Kn.	xxx	xxx	N		C. Naturalistas
Fischer FBSII US 8 x 70	8	at side of Pahoehoe layer	OK	Failure 5,5kn.	xxx	xxx	N		C. Naturalistas
Heco MMS 10 x 60	9	at side of Pahoehoe layer	OK comes out 3mm, bended head	Failure 2kn.,	xxx	xxx	N		C. Naturalistas
Fischer FBSII US 8 x 70	10	welded AA lava	OK	OK	2 x FBS test OK, 1 x MMS Failure 6kn	xxx	Y/N	re-use is dubious	C. Gentes
Heco MMS 10 x 60	11	welded AA lava	OK	OK	OK	xxx	Y		C. Gentes
Fischer FBSII US 8 x 70	12	welded AA lava	OK	OK	OK	MMS Failure at 8Kn.	Y	Test E = pull out	C. Gentes
Fischer FBSII US 8 x 70	13	welded AA lava	OK	OK	2 x FBS test OK, 1 x MMS Failure 5kn		Y/N	re-use is dubious	C. Gentes
Fischer FBSII US 8 x 70	14	hydrothermal alterated black basalt ***	OK	OK	OK comes out 1mm.,	Failure at 9Kn.	Y		C. Tinguaton
Fischer FBSII US 8 x 70	15	hydrothermal alterated black basalt	xxx	xxx	xxx	xxx	xxx	Rock is too hard. Anchors get stuck halfway	C. Tinguaton
Fischer FBSII US 8 x 70	16	clasted basalt (welded small rocks)	Failure at 4Kn.	xxx	xxx	xxx	N		C. Tinguaton
Heco MMS 10 x 60	17	hydrothermal alterated basalt walls of Geysir	OK	OK	2x MMS OK, FBS cannot be screwd in (rock too hard)	xxx	Y	Rock is too hard for FBS, Steel of MMS is weaker material	C. Tinguaton
** before re-use of the holes , these were not cleaned out by air, unless stated in the test results									
*** hydrothermal alterated black basalt can be found near fumaroles and former Geysir shafts. This particular rock has a hard glassy toplayer, more soft inside,									
no airbubles inside and of a very homogeneous nature. The basalt of the walls of fumarolles and Geysir shafst is alterated due to the high temperature and chemical									
alteration causing the walls to become in some case as hard as glass									

Fig. 3 overview on the test which have been done with their results. Failures in red colour

The tests where performed in abandoned areas which had signs of former mining and disturbance of the geological landscape. After the tests were finished, the bolts were removed and the remaining drill holes were closed with the surrounding rock particles

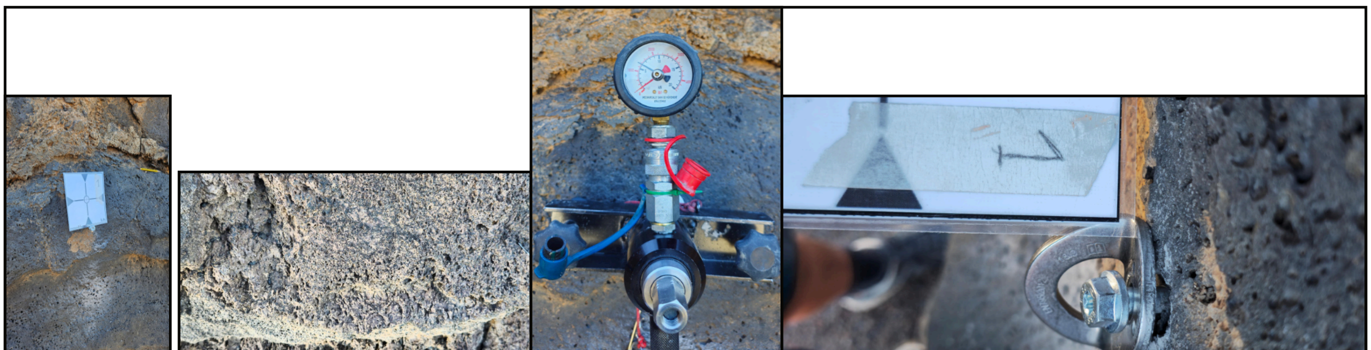


Figure 4 (a–d). Overview of test site 1, showing the black basalt rock type, the 6 kN pull-out test setup, and the observed movement at test (in column) D under an 8 kN load.

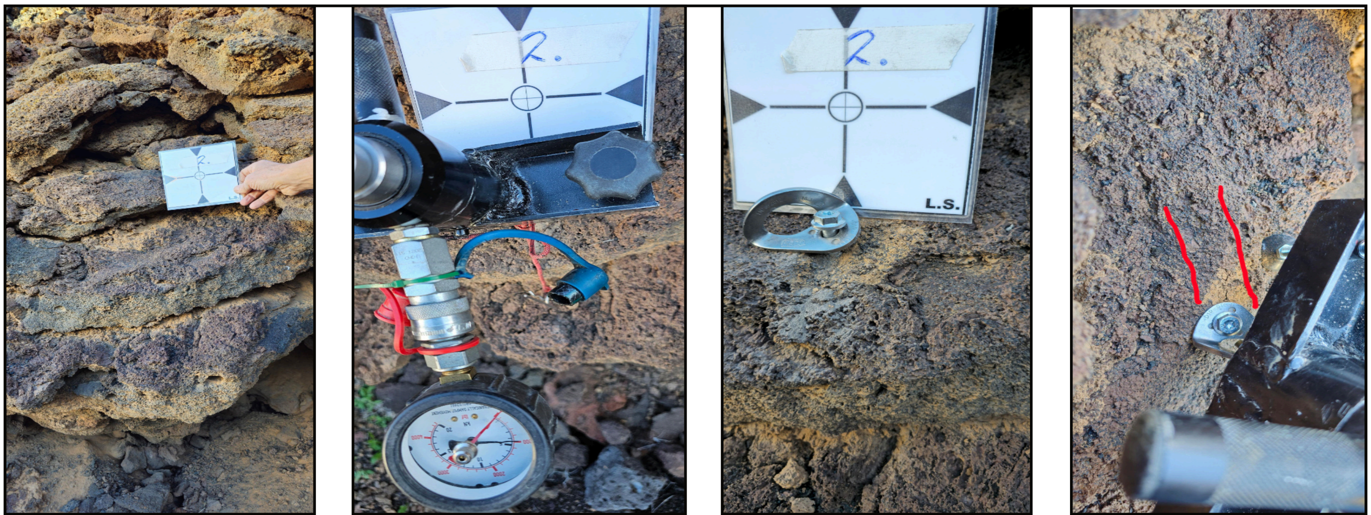
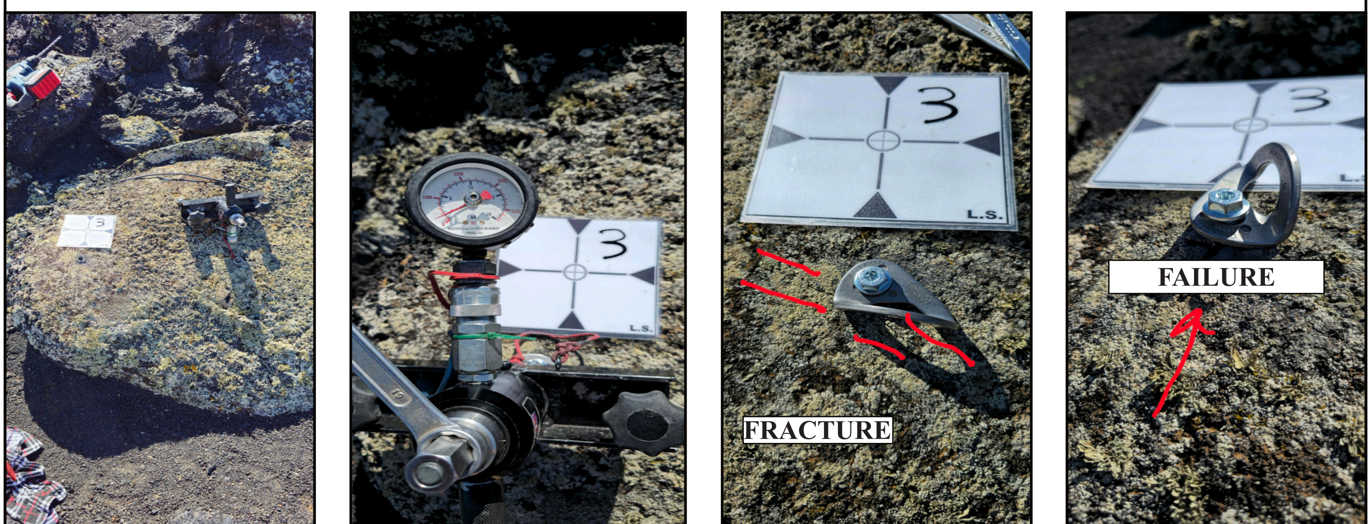


Fig. 5a, b, c and d, Showing location of test site 2, type of slab crusted lava flow, cracks and failure at 4kn



Location of the anchor

Fig. 6a, b, c and d, Showing location of test site 3, on top of Pahoehoe lava, cracks and failure at 1kn

Fig.6e showing the similar test site situation of test 3 and 4

Fig. 7a, 7b and 7c showing location of test site 7: At the side of a Homogeneous looking pahoehoe lava slab .
Fig. 7d showing failure at 5Kn. at second time re-use of the same anchor.

Fig. 8a – 8c showing the location of test 13, welded AA lava
Fig. 8d showing failure at 5Kn at second time re-use of the hole by a MMS anchor

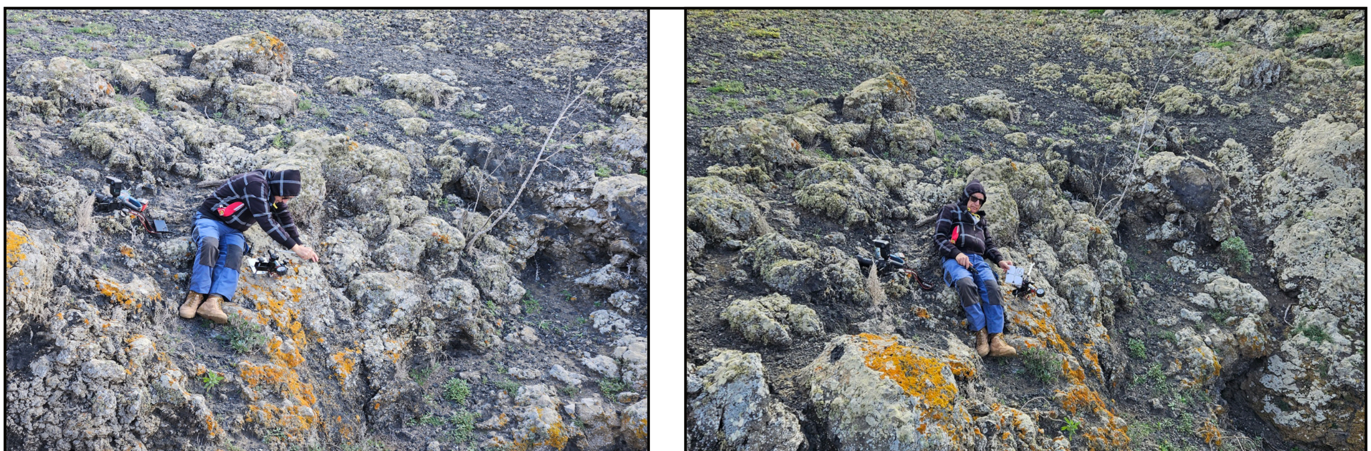


Fig. 9a – 9c showing the location of test 16, clasted basalt (welded small rocks). Failure at 4Kn.

Conclusion:

Re-use of self-tapping screws presents several problems. One key factor is whether the drill hole is properly cleaned with air before re-use. If the hole is not cleaned, sand and fine rock particles remain inside and can damage the threads, leading to degradation of the thread profile and a significant reduction in the anchor's holding strength after re-installation.

In our observations, the Heco MMS anchors are notably softer than the Fischer FBS II. The threads of the Heco MMS are weaker, and the bolts themselves are more easy to bend.

According to the previously mentioned investigation reports, screw anchors are not suitable for multiple use in regularly visited caves. Pre-drilled holes are designed for single use only. Re-using them can damage the threaded surface due to dust and small rock particles remaining in the hole. Even when using anchors of the same brand but different pre-manufactured lengths, the threaded hole may still be compromised, as the number and geometry of the serrated lead threads differ between bolt sizes.

Mixing different brands of screw anchors in a previously used hole can seriously compromise the reliability of the installation. Each manufacturer produces anchors with slightly different thread pitch spacing and diameter, which will damage the existing threads within the hole and result in a loss of anchoring strength in the rock.

1) Re-use

Re-use of self-tapping screw anchors in volcanic rock is not recommended, unless reliable backup anchors are in place, the rock is of high density and homogeneous structure, and you are 100% confident in the strength and integrity of the installed anchor in the re-used hole.

The use of newly drilled and installed self-tapping screw anchors in volcanic rock can be considered as an effective solution while exploring — provided that several safety measures are followed. Multiple anchors should always be installed, and the rock must be carefully inspected for cracks, consistency, hardness and structural soundness.

During drilling, the installer must continuously assess whether the rock feels solid and compact, free of air or gas bubbles, and provides a steady and reliable drilling response — something that only an experienced installer can accurately judge. After drilling, the hole should be thoroughly cleaned with air. When tightening the self-tapping screw anchor, the tapping process should feel firm and consistent throughout.

The only practical way to verify the soundness of the installation is by achieving the appropriate tightening torque once the anchor head is fully seated against the hanger.

2) Use Conditions

Yes, self-tapping screw anchors can be used in certain types of volcanic rock, but only under specific and controlled conditions:

- - For exploration purposes only, and limited to one-time use.
- - Installation must be performed exclusively by experienced users familiar with self-tapping screw anchors
- - Anchors should be placed only in solid, homogeneous, and reliable rock which is considered strong and dens enough during drilling
- - Anchors should be loaded in shear direction only, not subjected to axial pull-out forces.

3) Installer Competence .

The caver must be experienced in installing this type of anchor and he possesses the necessary skills to assess — by sound, observation and feel — whether the rock surface is suitable for installation. He must also have the skills and experience to determine whether the installed anchor is sufficiently reliable or if additional backup anchors are required. It is important to note that no practical on-site method exists to directly verify the strength or reliability of this type of anchor once installed.

It should be clear to everyone that natural anchors are always the first choice when installing rope or ladder systems. Only when natural anchors are unavailable or appear unreliable should bolts and hangers be used.

* *The author has been a manufacturer of anchors and anchor systems used in industrial fall arrest for more than 15 years. Furthermore, he has been working for over 10 years in European standardization working groups dealing with industrial and recreational fall arrest systems.*
** *The co-author has been a technical leading engineer for more than 50 years*

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