Testing of South and Mid Wales Cave Rescue Team Bolt Anchors

6 expansion type 'bolt' anchors were obtained from SMWCRT's store on 18 April 2015 as listed in Table 1 along with 6 Petzl Couer hangers. All anchors were 12mm diameter and came with a nut and washer. The nuts for all anchors bar No. 6 were marked 'A4' indicating they were Type 316 stainless steel. The washers had no indication of their steel. The Couer hangers were provided with a 12mm hole and marked with 25kN.

No.	Manufacturer	Type	Steel	Description
1	?		316 SS	
2	?		316 SS	
3	Fischer	FAZ II	316 SS	
4	Hilti	HSA-R	? 316 SS	
5	?		316 SS	
6	?		?	? Zinc coated
Table 1 – Anchors Used (? Indicates unconfirmed information)				

All the anchors were placed in sound limestone whose surface was dry, by first drilling a 12mm OD hole using a battery powered SDS drill to a depth in excess of the anchor. The dust in the holes was then removed by simply blowing down them using a pump (rather than a tube and lung power). The anchors were driven into the holes using the standard small hammer provided in the rescue kit with hanger, washer and nut on until the nut was tight against the rock surface. Each nut was then done up tight using a small (12cm length) adjustable spanner, backed off roughly a half turn and then done up roughly a quarter turn. The BCA anchor puller was then connected to the hanger using a 16mm diameter U bolt, see Figure 1. (Figure 1 shows the puller connected to a Bolt Product anchor.)

Figure 1 – BCA Anchor Puller

Each anchor was then pulled in axial mode by hand pumping hydraulic liquid into the ram. It is acknowledged that the Couer hangers are marked for use in the radial (shear or horizontal to the

rock) direction. The load cell provides a signal to a hand held reader which also has the facility to record peak values. Details of the peak forces and other features are recorded in Table 2.

No.	Type / Steel	Peak Force kN	Failure Mode	Overall length cm	Length Protruding cm	Length protruding post failure cm
1	316 SS	38.9	Hanger Snap	12	2 ½	4
2	316 SS	44.3	Hanger Snap	12	2 ¼	4 ½
3	FAZ II	31.2	Hanger Snap	11	2	3
4	HSA-R	30.1	Hanger Snap	12	2 ¼	3
5	316 SS	35.4	Hanger Snap	12	2 ½	4
6	? Zinc coated	22.0	Bolt sheared	9.5	2 ½	-
Table 2 - Results						

Photographs of each failed anchor are presented at the end of this note. Videos were taken of each test and are available on request. Although the hangers snapped for Anchors 1 to 5, the bolt stem of these anchors was bent, though the thread was intact and nuts were easily taken off to release the broken hanger. The hangers clearly performed better than advertised even though the load direction was not in accord with manufacturer's instructions.

There are two British Standards covering anchors, BS EN 795:2012 for personal fall protection equipment anchors and BS EN 959:2007 for mountaineering anchors. There is also a UIAA standard UIAA 123 2009 for mountaineering anchors. EN795 specifically prohibits such anchors from use in sporting situations. However, EN795 requires Type A structural anchors to hold a load of 12kN force for 3 minutes. EN959 requires an anchor to withstand a 15kN axial load. UIAA 123 requires an anchor to withstand a 20kN axial load. All anchors meet the axial load requirement of EN959 and UIAA 123. Given the anchors were extracted by hand pumping, loads in excess of 12kN were applied for at least ten seconds. It seems likely that the anchors would also meet the axial load requirement of EN757.

Anchor No. 6 failed in a different mode. This has been observed before and is thought to be due to a change in fulcrum location as the hanger lifts off the rock, see Figure 2 which enhances the leverage force on the anchor.

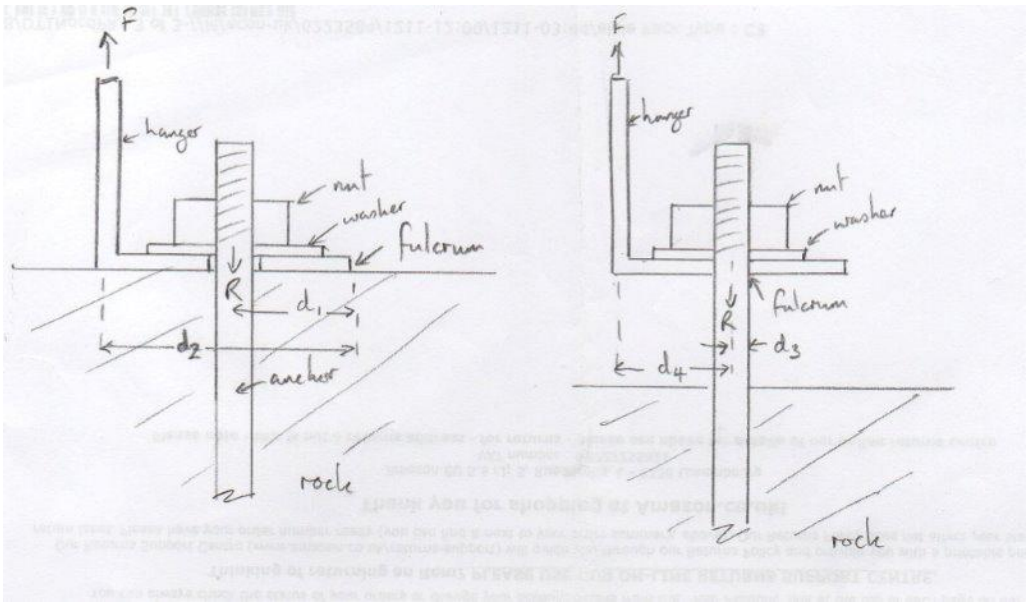

Figure 2 – Effect of Change in Fulcrum location

Although the three unnamed Type 316 SS anchors gave the highest peak forces, given the failure mode was the hanger for the five anchors, it seems more likely that these results are just a reflection of the distribution of the hangers rather than a difference due to the different type of anchors. Hence taking Anchors No. 1 to 5 inclusive, the mean value was 36.0kN, standard deviation 5.8kN (or 16%). This compares favourably with values for the various 'P' hangers, see Table 3.

Anchor Type	*No. tested*	*mean kN*	*SD kN*	*% SD*	*k*	*5% fractile value kN*
DMM Eco	*23*	*39.8*	*9.5*	24	*2.16*	*19.4*
Pico trial batch	*33*	*33.6*	*5.2*	15	*2.08*	*22.8*
Pico batch 2 Horseshoe Quarry #	*30*	*27.9*	*4.1*	15	*2.08*	*19.4*
Pico batch 2 Ingleton #	*30*	*34.9*	*6.2*	18	*2.08*	*22*
Bolt Products / Rawl resin	*33*	*35.2*	*4.7*	13	*2.08*	*25.4*
Bolt Products / KMR resin	*32*	*44.9*	*8.7*	19	*2.08*	*26.8*
S Wilson field work using Fischer	*36*	*35.7*	*1.1*	3	*2.04*	*33.5*
BP / Fischer resin Penwyllt quarry &	*31*	*38.7*	*4.9*	13	2.08	28.5
BP / Fischer resin Penwyllt quarry flooded holes	12	35.6	5.4	15	2.4	22.4
Rescue 12mm Bolt anchors Penwyllt quarry @	5	36.0	5.8	16	3.4	16.2
# excluded metal failure results, & excluded wet hole results,						
@ batch size too small to determine normal distribution						

Table 3 Summary Data for all resin placed anchors used in the NCA & BCA Scheme

They would, save for the condition of having a normal distribution, meet the criterion adopted by BCA's E&T committee for anchors. That criterion is that 95% of the anchors in the population, based on the tested sample would fail at a force level greater than 15kN. E&T have not considered the potential impact of the higher axial failure criterion given in the UIAA standard. However the different failure mode of the zinc coated anchor undermines such a claim and would require further investigation.

Our thanks go to Lisa Boore and Dan Thorne for their help in conducting the tests.

V Allkins
B Mehew
July 2015

No. 1 	No. 2 
No. 3 	No. 4 
No. 5 	No. 6