

Report on Testing of Bolt Product Anchors using Fischer Resin at Penwyllt Quarry, South Wales

A set of 33 Bolt Product Type 304 Stainless Steel anchors with 100mm long shafts (Ref no GP8 -100-16A2) were placed in the quarry using Fischer V 360 S resin in two batches. The first in early November 2014 consisted of 5 anchors. The second on 29 November 2014 consisted of 28 anchors. To maintain speed of placing, only anchor 60 in the second batch was placed in a notch; the rest were not. All the anchors in the first batch were placed in notches. The final anchor was placed by 12.50 pm on 29 November.

The placement procedure used was to drill the holes using a 16mm SDS drill, check for depth, blow the holes free of dust, then wash them several times using water and a bottle brush before notionally drying the hole using a chemise cloth. The anchors were degreased using lighter fluid and paper towel. Each hole was filled with resin and the anchor placed into the hole. A small sample of resin was taken in a short length of 15mm OD clear plastic pipe to provide for a reference if required and as a check against poor mixing. Records were also kept of which anchor was placed with which resin. The cartridges of resin were placed upright for approximately 2 hours before use to encourage any air within the two compartments of the cartridge to rise to the top and thus be expelled first. There was no indication of poor resin mixing at any point during the placement of the anchors. (Cartridge B had its nozzle changed since the resin had set in the time gap between placements of anchors 106 and 107.) Surplus resin was wiped away leaving a smooth profile. Two holes were found to have visible quantities of water in them. Owing to time constraints, anchors 110 and 118 were placed in them without removing the water.

The anchors were extracted with an axial force on 30 November. The pulling order reflected to a limited extent the placement order such that the resin for every anchor had had at least 24 hours curing time. The temperature was not measured but the day was mild with sunshine. The records for Cross Hands, some 30km to the east and at 170m ASL (compared to the quarry at 350m) indicate the minimum overnight temperature was 6.1C whilst those for Llangorse, some 30km to the west and at 250m ASL indicate the minimum temperature was 9.2C. This level of temperature is not thought to significantly impact on the curing time of the resin (Fischer claim 90 minutes for 5 to 10C) in relation to the 24 hour period.

The peak forces recorded and other related records are given in Table 1. Related photos and movies, together with the spread sheet data calculations can be downloaded from <https://drive.google.com/file/d/0B0RTfmWzkLQMMnB5U2NERV9sNUE/view?usp=sharing>. (Print outs and electronic copies will be lodged in the British Caving Library.) The results from the two holes found to have water were excluded from the analysis of the data. Anchor 110 which failed at 10.2kN was thought to have not had its hole properly cleaned; the cured resin surface being significantly different to other resin samples in having sub millimetre sized bubbles sunken into the resin (hence reducing the resin to rock contact area). The incorporation of the anchor 110 data point caused the whole data set to fail its normal distribution test and was therefore discounted. Anchor 118 was discounted as it also had water in the hole, even though it failed at a peak force of 39.8kN. This points to care being required in ensuring drilled holes are properly cleaned. Given the test bed situation where two people were working on the holes at the same time, it seems less likely that such a mistake might arise down a cave where work on a pitch is usually limited to one person.

The mean value of the remaining 31 anchors was 38.7kN with a standard deviation of 4.9kN (13% of mean). The data set was found to be normally distributed. The 5% fractile value was thus 28.5kN which is comfortably above the acceptance criterion of 15kN for an axial pull. Table 2 shows summary data for the range of anchors placed under the NCA and BCA schemes. Fischer V 360 S resin gave a better performance than KMR resin, assuming the difference in rock has no impact.

Several observations were made whilst pulling the anchors. The first was that the twisted shaft causes the anchor to turn on being extracted, as had been noted before. The design of the BCA anchor puller is such that this twisting force is transmitted through the U bolt and up the threaded bar shaft to the joint between it and the load cell. What was noticeable was that in many cases it was clear that the resin metal bond had broken and that the anchor was initially being extracted whilst leaving the resin in place. But part way out this mode of extraction suddenly changed and some, perhaps half of the resin in the hole was then pulled out, seemingly attached to the anchor. From memory, this change in mode was often around the same time that spalling of the rock became significantly. A few anchors came out and left the hole clear such that one could see down the hole. These showed the resin in place and with a neat imprint of the anchor. It would thus seem that a significant failure mode was first the metal / resin bond failed. However the anchor was still held well in place by the mechanical interference between metal and resin. But after part extraction of the anchor, the remaining extraction would cause the resin / rock bond to fail in the top half of the hole whilst also causing the rock in the top 2 to 5 centimetres to spall.

The second set of observations related to the degree of spalling occurring on extraction and the extent to which the hole was reusable for placing another anchor. The BCA puller was specifically designed to place the reaction force back into the rock well away from the zone of potentially affected rock. It is not clear if an extractor placing this reaction force back into the rock close to the anchor would substantially reduce the degree of spalling. Around 50% of the holes suffered sufficient spalling to make the location not reusable. This would make the anchor unattractive on conservation grounds.

The third observation is that failure to properly clean a hole before placing the resin can cause the anchor to system to significantly reduce its strength.

Part of a test bed using Bolt Product Type 304 Stainless Steel anchors using Fischer V 360 S resin in wet holes was placed but the work was not completed due to lack of time. The planned return was cancelled owing to a weather forecast predicting near zero temperatures. This work to determine the influence of leaving a hole full of water and displacing it using the resin remains to be completed. But Fischer V 360 S resin was found to be satisfactory in notionally dried holes.

The permission of the South Wales Caving Club to use the Penwyllt quarry for testing these and other anchors is gratefully acknowledged.

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January 2015

Table 1 - Type 304 BP anchors using Fischer V 360 S resin Penwyllt 29 & 30 November 2014

Pulling order	BP no.	kN force	comment	notched	resin sample	resin	reusable location	photos		
1	60	36.46		yes	before & after	B	no	0	2568, 2571 to 76	
2	58	26.84		no	after	A	no	0	2568, 2577 to 79, 81	
3	59	41.01		no	after	A	no	0	2568, 2582 to 85	
4	56	41.78		no	after	A	no	0	2568, 2586 to 93	
5	57	36.51		no	after	A	yes	1	2568, 2594 to 98	
6	101	25.26		no	after	B	yes	1	2570, 2599 to 2604	photos show 111 incorrectly numbered
7	102	43.87		no	after	B	yes	1	2570, 2605 to 09	
8	103	37.61		no	after	B	yes	1	2570, 2610 to 12	note 12 shows resin at bottom of hole
9	104	36.53		no	after	B	yes	1	2569, 2613 to 16	
10	105	30.02		no	after	B	yes	1	2569, 2617 to 21	
11	106	37.24	1st movie from note made at time, shows time in sync between cameras	no	after	B	yes	1	2569, 2622 to 26	
12	127	44.46	2nd movie based on times of cameras, placed preceding week	yes	no	A	?	0	2627 to 30	
13	128	39.93	placed preceding week	yes	no	?	?	0	2631 to 36	
14	107	40.93	3rd movie based on times of cameras	no	after	B new nozzle	?	0	2637 to 42	note 42 shows resin at bottom of hole
15	109	39.84		no	after	B new nozzle	?	0	2644 to 55	
16	125	43.12	placed preceding week	yes	no	A	?	0	2656 to 60	
17	108	37.36		no	after	B new	no	0	2661 to 83	

						nozzle					
18	110	10.24	found with water in hole, now ? If properly cleaned	no	after	C	yes	1	2684 to 89	85, 6 & 7 show curious surface to resin indicative of poor bonding to rock	
19	123	46.16	placed preceding week	yes	no	A	yes	1	2690 to 93		
20	111	42.04		no	after	C	yes	1	2694 to 98	note these photos are correctly labelled	
21	112	38.49		no	after	C	?	0	2699 to 702, 04 & 05	note 705 shows resin at bottom of hole	
22	115	38.5		no	after	C	?	0	2706 to 14		
23	114	41.91		no	after	C	yes	1	2722 to 28		
24	113	37.19		no	after	C	no	0	2729 to 37		
25	118	32.85	water logged hole	no	after	C	yes	1	2739 to 41		
26	122	47.36		no	no	A	no	0	2742 to 45		
27	117	37.52		no	after	C	no	0	2747 to 51	note 51 shows resin at bottom of hole	
28	116	37.17		no	after	C	no	0	2752 to 57		
29	129	35.75	placed in vertical face	no	after	C	no	0	2758 to 64		
30	130	35.42	placed in vertical face	no	after	C	yes	1	2765 to 67		
31	119	39.26	placed in vertical face	no	after	C / D	yes	1	2768 to 70		
32	120	44.27	placed in vertical face	no	after	D	yes	1	2771 to 74		
33	124	41.14	placed in vertical face into notch, placed preceding week	yes	no	A	yes	1	2776 & 77		
							sum	16			
									2793 to 99	photos of field note book records	
									2790	photo of all anchors	
									2792	photo of all resin samples	
									2563	location of work	

Table 2 Summary Data for all resin placed anchors used in the NCA & BCA Scheme

<i>Anchor Type</i>	<i>No. tested</i>	<i>mean kN</i>	<i>SD kN</i>	<i>% SD</i>	<i>k</i>	<i>5% fractile value kN</i>
<i>DMM Eco</i>	23	39.8	9.5	24	2.16	19.4
<i>Pico trial batch</i>	33	33.6	5.2	15	2.08	22.8
<i>Pico batch 2 Horseshoe Quarry #</i>	30	27.9	4.1	15	2.08	19.4
<i>Pico batch 2 Ingleton #</i>	30	34.9	6.2	18	2.08	22.0
<i>Bolt Products / Rawl resin</i>	33	35.2	4.7	13	2.08	25.4
<i>Bolt Products / KMR resin</i>	32	44.9	8.7	19	2.08	26.8
<i>S Wilson early concrete work</i>	6	42.5	1.2	3	3.09	38.8
<i>S Wilson field work RAWL</i>	25	34.9	3.5	10	2.13	27.4
<i>S Wilson field work using Fischer</i>	36	35.7	1.1	3	2.04	33.5
<i>BP / Fischer resin Penwyllt quarry &</i>	31	38.7	4.9	13	2.08	28.5
# excluded metal failure results & excluded wet hole results						