BCA Equipment and Techniques Committee – Draft Minutes

Meeting held at three locations linked by Webex on 15 November 2015 commencing at 11:15 am

Present: Jules Barrett (DCA) JB [1], Faye Litherland (CSCC) FL [2], Bob Mehew (Rope Test Officer) BM [2], Nick Williams (Convenor) NW [1], Richard Vooght (DCUC) RV [2], S Wilson (CNCC) SW [3]

Locations : [1] = NW's, [2] = FL's, [3] = SW's

1. Apologies for Absence: S Natynczuk (ACI) had sent his apologies.

2. Chairman's Opening Remarks: NW noted that this was the first electronic meeting to be held by BCA. He also welcomed RV to his first meeting of E&T. FL apologized for causing the delay to the start of the meeting which was due to an emergency on her farm.

3. Notice of Items to be raised under AOB: NW noted that he wanted to obtain feedback on the meeting using the web. FL wanted to discuss the size of hole used by BP anchors. BM wanted to discuss extracting BP anchors. NW proposed these two items be covered by item 8.

4. Minutes of Previous Meeting: The minutes were accepted and signed.

5. Matters arising not covered elsewhere including review of actions in progress:

5A Actions from Previous Meetings

2/11/14

Action 16.2.1 - FL to provide a draft User Requirement Specification for Anchors to NW for circulation within E&T. – Following a discussion it was agreed that this would be reduced to a set of bullet point requirements authored by FL & BM. Action closed and new action raised.

Action 5A.1 FL & BM to produce a set of bullet points of key requirements for an anchor.

15/3/15

Action 6.1 - BM and VA to pull existing 10 BP / Fischer anchors and review if data is sufficient to not need testing a further 23 anchors. – BM reported this had been done and would be covered under item 6. Action closed.

Action 7.1 – GT & BM to produce a brief report summarizing the outcome of anchor work in North Wales slate for general publication. – BM requested this be dealt with under item 7. Action closed.

Action 7.2 – BM to produce a full report on the anchor work in North Wales slate. – BM requested this be dealt with under item 7. Action closed.

Action 9.1 – NW to provide comment to SW on IC anchor training manual and then circulate amongst the committee. - As it was unclear as to what had been achieved, SW agreed to send a copy to NW. Action continues.

Action 5A.2 – NW to provide comment to SW on IC anchor training manual and then circulate amongst the committee.

Action 12.2 – SW to obtain M24 fine threaded bar for making up a replacement anchor extractor. – SW reported that he had gone for M16 as he felt it would be strong enough together with other modifications plus it was cheaper. These included using a specially made long nut with an integral flange which better spread the load onto the thrust bearing and a collar near the base of the extractor to ensure the load up the extractor remained central. The IC anchor web site provided photos of the new extractor (see http://www.resinanchor.co.uk/5.html). Action closed.

Action 12.3 – RK to undertake testing of a batch 5 Titanium and 5 HCR / Duplex Bolt Product anchors. – RV said that this had been undertaken and should be covered under item 7. Action closed.

5B Other Points Arising: There were none.

6. Investigations/selection of resins: BM reported that the follow up work had been completed in April and a revised report posted on the BCA web site, see http://british-caving.org.uk/wiki3/lib/exe/fetch.php?media=equipment_techniques:bp_anc_fischer_resin_report_150418.pdf . A further 12 anchors were placed using Fischer V 360 S resin in flooded holes to check the impact of totally wet conditions on the resin. The results showed a normal distribution with a 5% fractile value of 22kN, compared to 28kN for the use of Fischer in damp holes.

FL asked if the resin was styrene free. BM confirmed it was.

FL asked about continued use of KMR resin. BM noted that at the last meeting, Roger King had reported that he had had a problem with KMR resin resulting in one anchor coming out with only 8kN force and low values on 4 others. (This refers to the data reported in Table 1 in Appendix 1.) BM has had the advantage of reading RV report (to be presented under item 7) which indicates that the rock was not the cause of the low values (it with stood very high pull out values when tested with a different anchor and resin). The thinking was that it was due to poor mixing of the resin as well as the resin being reported as rather 'gritty'. This raised a question over whether the resin had been used to install anchors for use in caves. BM had sought information and Glenn Jones had supplied information indicating that the batch of resin used by Roger had been purchased by Roger and thus had not been used by other installers. NW commented that this supports his concerns over the reliability of the KMR resin and SW's concerns over effective mixing by resin held in coaxial tubes.

The committee reaffirmed that Fischer resin should only be used hence forth. NW noted he had made a bulk purchase of 24 tubes from FastCo and still held some 10 tubes dated October 2016. One benefit of the choice of resin was that it was also available via Screwfix though it was more expensive (roughly £14 v £10). NW had also purchased 6 applicators. It was understood that V Allkins (CCC) had one and SW confirmed he had one. RV indicated he would need both applicators and resin and requested 2 tubes. It was agreed that 2 applicators would be issued to SUI, DCA, CSCC & DCUC.

Action 6.1 – NW to issue two Fischer resin applicators to SUI, DCA, CSCC & DCUC plus 2 tubes of Fischer resin to DCUC.

NW noted that whilst the situation was more stable, he wondered if it would be appropriate to find another resin. FL noted that Tom Chapman had commented on suitable resins and agreed to make enquiries and report back.

Action 6.2 – FL to contact Tom Chapman to obtain suggestions for an alternative suitable resin.

NW asked what testing program would be required. BM suggested that the Fischer program should be repeated with 33 anchors in clean and damp holes plus 10 in flooded holes though given we could now test for normal distribution in field, smaller numbers might be required. He expressed a concern as to what quarry could be used given the large area of flattish rock required. FL noted Westbury quarry might be available. BM noted he had once used several boulders in Fairy Cave quarry but felt that boulders were not entirely practicable. He asked if concrete could be used. FL suggested using other rock substrates. SW reported that he was using kerb stones for training, though the more easily available 5 by 10 inch stone was roughly the same depth as an anchor. He had sourced a couple of 6 by 12 inch kerb stones but these were much less available. FL suggested railway sleepers but it was pointed out that these contained reinforcement and hence would not be suitable. NW was concerned about disposal of concrete or used kerb stones. It was agreed that all members should make enquires about the availability of suitable quarries.

Action 6.3 – All members to seek alternative quarries for testing anchors.

JB enquired about nozzles. SW reported that he had used several types without problem but did ensure the resin was properly mixed by extruding some to check on the colour before using, as well as extruding a bit more post filling the hole to confirm the mixing process had remained OK. NW noted he had some 20 KMR nozzles which could be used up.

7. Report on anchor activities in the regions:

7A CNCC: SW reported that CNCC now had 6 people trained to place IC anchors with a further 3 awaiting training. Some 126 IC anchors had been placed. One Peco anchor in Stream Passage had been extracted with his tool and replaced as a trial. CNCC had agreed to not use BP anchors.

7B DCA: JB reported that DCA had 10 people trained. Bob Dearman was DCA's Equipment Officer but he was leading most of the activities. Due to work demands, these were planned for the winter months but several loose anchors had been replaced a few weeks before. Plans were in hand to place more anchors.

JB noted that he was concerned about conservation of anchor locations. Using the existing process of drilling down the side of the anchor to break the resin bond to the rock would leave a large hole which when a second hole was placed would leave little rock. BM noted that no proper tests of BP anchors in larger holes had been carried out but some experience from SW work (see http://www.resinanchor.co.uk/3.html) where he placed IC anchors in an oversized 18mm (instead of 12mm) hole indicated resin was as strong as rock. FL noted this was in line with her request for an AOB item. NW proposed that this should be further discussed under item 8.

7C DCUC: RV reported that work on testing anchors had covered 3 types of rock, see Appendix 1. Roger King had placed 5 BP anchors in Devonian Limestone and the results were not encouraging.

One failed at 8kN due probably to poor mixing of the resin. The resin was noted to have a granular texture. BM noted that this raised a concern about the quality of the resin. He had made enquiries and found that the batch of resin used by Roger was separate from those issued to other installers.

RV went on to report that 4 BP anchors had been placed by Roger in granite and produced more consistent results above 25kN. Roger had also placed 4 anchors in Killas which gave low results between 13 and 20kN. RV had subsequently placed 6 BP anchors in a different Killas exposure which had given satisfactory results of between 30 and 44kN.

RV had then placed one titanium anchor purchased from Titan Climbing and 3 BP HCR anchors in Devonian limestone. The titanium anchor had broken in the metal head at 17.8kN. NW proposed this was discussed after the HCR anchors had been discussed. The 3 HCR anchors had failed between 58 and 64kN. NW asked as to where HCR anchors were to be used. RV reported that DCUC wanted to place between 6 and 8 anchors at Berry Head which was in Torquay Limestone and by the sea. (The entrance requires a traverse which he had yet to assess.) BM suggested that to test the rock, only 5 more HCR anchors would be required. NW noted that it was unclear if the BP HCR anchors had been confirmed to meet EN 959. BP's web site indicated that the Sea Water series was supplied in 1.4462 duplex stainless steel which was explicitly linked to EN 959. But NW understood he had been supplied with HCR anchors in 1.4529 super austenitic stainless steel which had no such link. Furthermore whilst BP's protection bolts were clearly stated to have been "tested to EN959 by TUV Sud" no such claim was made for BP's Sea Water series or HCR anchors. BM asked if E&T testing 30 HCR anchors would be sufficient. FL suggested that we should also obtain assurances on manufacturing process; for example she was unclear as to why a passivation and then polishing process was required. Surely the polishing removed the passivation layer. NW then asked about the number of HCR anchors required. He suggested 30 for testing, 10 for DCUC to place at Berry Head and 10 as stock for use by others such as in mines. It was agreed that NW should write to Bolt Products to seek further information.

Action 7C.1 – NW to write to Bolt Products seeking assurances on material selection and production process providing a repeatable product, why passivation was required given polishing would remove it (if indeed it was applied to the HCR anchor) and whether the HCR anchor had been tested by TUV Sud.

The committee discussed the experience with the titanium anchor and the response by the manufacturer on being informed of the failure mode and peak force. It decided that since the HCR anchors showed promise, there was no need to pursue the use of titanium anchors. RV agreed to extract the shaft of the anchor, take a series of photos and return the bits plus the remaining 9 anchors to NW.

Action 7C.2 – RV agreed to extract the shaft of the titanium anchor, take a series of photos and circulate them to E&T and return the bits plus the remaining 9 anchors to NW.

The committee agreed to NW not pursuing a refund for the titanium anchors.

7D CSCC: FL reported little progress other than an anchor in Swildons had been reported as being loose.

7E CCC: NW noted he had had no report from V Allkins.

BM stated that two pieces of work had been conducted in Wales in addition to the work under item 6. The first had been conducted following the work on Fischer resin in flooded holes and looked at

expansion anchors which were used by SMWCRT. The work had been reported at http://british-caving.org.uk/wiki3/lib/exe/fetch.php?media=equipment_techniques:expansion_anchors.pdf . 5 stainless steel and one probably zinc coated steel expansion anchors were tested. The 5 stainless steel gave a reasonable peak extraction force (mean 36kN, 5% fractile 16kN) and broke at the hanger which was rated at 25kN. However the other zinc coated broke by the bolt shearing following lift off of the hanger. This failure mode had previously been identified in 2013 North Wales work and related to the shift in fulcrum location from on the rock at the side of the bolt, thus magnifying the force on the bolt by possibly as much as a factor of two. The work had been drawn to BCRC's Equipment Officer's attention with a suggestion for further work. BM commented that he had had no response. NW suggested that expansion anchors were not a priority for E&T. FL observed that they were used. BM suggested that obtaining evidence on the acceptability of using a larger hole and identifying an alternative resin were higher priority.

BM went onto note that he had produced a full report on the North Wales slate work which had been circulated to members. (Given the size of the document, it will be posted up on the BCA web site at http://british-caving.org.uk/wiki3/doku.php?id=equipment_techniques:anchor_scheme .) BM noted that the task had been complicated by the considerable number of variables in the work. The conclusions were:

> A few extra samples are likely to improve the nature of the results by producing normally distributed sets of results for the major variables.
>
> The results show that BP anchors meet the E&T criteria for adoption in the four types of North Wales slate of Cwmorthin Back and Stripey slate, Cambrian slate and Briach Goch Corris slate.
>
> The results also show that both Collinox and 12mm Goujon expansion anchor coupled with the Coeur hanger meet both the European Standard and the UIAA criteria in the four types of North Wales slate.
>
> The results for Collinox anchors support a claim that Batinox anchors are likely to also meet the European Standard and the UIAA criteria in the four type of North Wales slate.
>
> The results show that IC anchors with KMR resin meet the meet the European Standard and the UIAA criteria in the four type of North Wales slate. Although the results are strongly indicative that IC anchors using Fischer resin would meet E&T's criteria, a new test set using the approved resin is required to be conducted before E&T should consider adopting the IC anchor for the four types of North Wales slate.

The report was noted. NW asked about a summary. BM stated that he had not produced one since he waited to obtain the committee's comments on the full report. He agreed to produce a summary which would be cleared by NW for use in the BCA newsletter.

Action 7E.1 – BM to produce a summary on the North Wales anchor in slate work for NW to agree.

BM sought the committee's agreement to designate the BP anchor for use in slate mines which are located in the four types of North Wales slate of Cwmorthin Back and Stripey slate, Cambrian slate and Briach Goch Corris slate. The committee agreed to this proposal without comment.

8. Loose anchors - identification, assessment/reporting, removal & replacement: SW reported that a number of anchors had been reported as loose in the Dales. These all seemed to be anchors placed using the Hilti resin in the early 90s and were not countersunk. He had noticed that 7 or the 8 anchors in Hardrawkin were loose and the worst were the 4 placed on Y hangs. This might point to a wearing mechanism dependent upon force of usage. He had been discussing developing a device to measure looseness with Sam Allshorn and BM but had not come to a conclusion. SW stated that he guessed that there might be 100 loose anchors in the Dales and declared an intention to go and inspect them in the coming months. SW felt that more information was needed before deciding on a need for a program of work and priorities. The records indicated that there were some 700 anchors placed in the Dales using Hilti resin. If we were talking about large numbers of anchors requiring replacement, then there was a need to prioritize them on some basis, perhaps those most loose or those most use. But SW affirmed that he did not want to do anything at the moment until he had gathered more information.

JB reported that there had been 2 reported loose anchors in Derbyshire which had been dealt with but a further 5 reports remained outstanding. JB noted some of the reported anchors were not at pitch heads.

NW observed that the committee needed to be confident that the anchors could continue to be used. If not should people be taking action? BM asked if JB could confirm whether the 7 reported loose anchors in Derbyshire had been placed with Hilti resin. JB was unsure and agreed to report back to BM.

Action 8.1 - JB to inform BM as to whether the 7 reported loose anchors had used Hilti resin.

(Post Meeting Note – JB reported after the meeting that only 3 anchors used pre 1996 and thus presumably Hilti resin, whilst the other 4 were positively identified as using Resifix R3+ resin.)

BM noted that the rock / resin bond has two parts, a chemical and a mechanical bond. If the chemical bond has gone as indicated by looseness of the anchor, then the mechanical bond can still hold the anchor in. He has heard of reports from Les Sykes and Bob Dearman that Hydrajaw's testing of loose anchors which had resulted in the anchors becoming jammed at 10kN. BM had also had one experience in one of Swildon's lifeline anchors on the twenty foot pitch which had been reported loose. He had tested it with the Hydrajaws and jammed it solid at 10kN. So he considered the mechanical bond will withstand a reasonable force. What he, Simon & Sam had been discussing was 'was there a potential wear mechanism which might erode this mechanical bond?'. He felt this was not a fast mechanism so the situation with loose anchors was not potentially catastrophic.

NW asked if any replaced anchors had come out at low force in the past. JB reported that the technique used in Derbyshire was to drill down the side of the DMM anchor within the resin, break the resin / rock bond and then extract the anchor. Typically it still took over 4kN to remove the anchor with the resin broken. BM noted that Bob Dearman had organized a testing of every anchor in Derbyshire to 10kN which suggested that there was no serious problem with existing placed anchors.

NW noted that this implied there was not likely to be any immediate danger from a loose anchor. However he felt that if there was evidence of some concern, then action should be taken as fast as possible. SW noted that the ones he had replaced had required 'quite a bit of pulling' to get out. He expressed the opinion that there was not a crisis but work was needed to ensure that if more anchors were found loose, then the situation did not develop into a crisis. NW summarized the position as there did not appear to be any information indicating a loose anchor was unsafe in

coming out at low force but if information did arise of such an unsafe anchor, the position should be reviewed as soon as possible.

FL emphasized that all cavers should be inspecting every anchor before they use it. BM also noted that anchors placed under the scheme are placed so that every anchor has a back up. SW noted the Y hang anchors in Hardrawkin undermined this back up. BM suggested that the evidence to date is that there is no crisis but that work was required to monitor and also undertake some proactive work.

BM sought the committee's agreement to seek copies of all records to see what might be learnt from previous replacements. He had got all records up to 2006 or so but wanted those up to date. NW was concerned that regions might object. FL responded that she felt CSCC would be content to share its records. BM reported that he had spoken with Les Sykes who was happy to provide the records for the Dales. JB commented that he would make enquiries. The committee agreed that BM should seek collate a set of records from the regions.

Action 8.2 - BM to seek copies of records from the regions and extract data on replaced anchors.

NB BM later made reference to UIAA work on resin, see item 9.

BM noted that experience with testing BP anchors indicated that the majority of anchor locations would be spoilt by rock spalling. Thus alternative techniques would be required to replace a BP anchor with another at the same location. FL suggested using a larger hole than the current 16mm so as to allow one to drill down the side in the resin to break the resin / rock bond. She suggested an 18mm hole.

SW confirmed that he had tested an IC anchor in a 12mm hole which he had reused at 12mm and then reused a third time after drilling the hole out to 18mm to mimic a hole left after extracting a DMM anchor. The peak force required to extract the replaced anchor was not significantly different from his range of values. BM claimed that this was encouraging evidence that the resin could cope with being used as a filler as well as bonding agent in larger holes. The key problem was cleanly extracting the BP anchor. JB noted that drilling down the side of a BP anchor was different because of the twisted shaft. It was suggested that to be able to cleanly drill down the side of a BP anchor might require a hole with a diameter of over 24mm (16 + two times 4mm being the smallest available SD drill). NW asked about using metal drill bits. BM noted that most resins were filled with silica / sand and thus he doubted if a metal bit would be capable. NW noted that drilling into stainless steel would be subject to many problems. JB suggested angle grinding the head off and then core drilling. NW felt he could offer his facilities to do this work. FL noted that there was also a need to show that a BP anchor could be used directly in an ex DMM 18mm diameter hole. It was agreed that this work was first priority. BM volunteered to draft a program and seek agreement by email, JB was prepared to help place anchors and NW was happy for the work to be done at his place.

Action 8.3 - BM to produce a draft program for agreement by the Committee on removal and replacement of BP anchors by email and then for NW & JB to help undertake it.

9. Rope test activities: BM reported that the rig was not taken to Hidden Earth due to a family emergency and that he was outstanding some work on ropes, notably Long Term Rope Test, Hand Lines and Cow Tails Knots. NW asked if BM had started looking for an apprentice. BM replied that

he had not but had hoped that with the development of the instrumentation on the Bradford Rope Test Rig he might be able to attract a final year university student to undertake a project on the rig.

FL asked about degradation of equipment with usage. BM noted the Long Term Rope Test work which showed considerable reduction in survival in dynamic drop testing after fairly small usage as also found by Pit Schubert of the UIAA for climbing rope back in the 1990s. He also noted that there had been a report on fatigue life of crabs (see http://web.mit.edu/sp255/www/reference_vault/Fatigue_Presentation.pdf) which indicated life in excess of 10,000 cycles for cyclic loads up to 8kN.

FL asked if work had been done on anchors and resin degradation. BM noted that he had forgotten to mention under the previous item that UIAA had started work on resin life time. He had hoped to be able to draw BCA's records together to produce a report for the UIAA on BCA's experience with resin based anchors. FL asked if anyone had access to a fatigue rig. NW noted that his business did have all the necessary components to make a suitable test kit but did not have the time to undertake the work. He also suggested that a specification was required for the work. FL and BM agreed to draft a specification.

Action 9.1 - FL & BM to draft a specification for fatigue testing of anchors placed in rock.

10. Static test rig: BM reported that no work done due to him being busy with other matters.

11. AOB

11.1 Peak Force requirements: FL enquired why pull shackles up to 60kN. BM noted that the shackle was part of the linking system used in testing anchors. As the E&T criteria required a peak force, it was necessary to use sufficient force to extract the anchor. The HCR anchors had required forces in excess of 60kN to extract them, hence the comment. FL accepted the explanation.

11.2 Maximum Force requirement for anchors: NW noted that in the delay before the meeting started, he had had a discussion with SW over specifying a maximum force for extraction of an anchor. SW reported that he had had an email exchange with Bolt Products over the topic of needed strength of anchors. BP were claiming they had the strongest anchor. SW took the view that it was much more important to have an anchor which whilst meeting the minimum force requirement also had a small spread of results. Having a high extraction force requirement created problems with rock failure and hence the conservation of anchor locations.

11.3 Stock of BP 316 anchors: NW noted he had an idea of how many HCR anchors to order and wished to also order some more 316 anchors from Bolt Products. He only had 20 remaining in stock and asked what future requirements of each region was. JB expressed the view that he should hold back from ordering any more until the questions over removal and replacement had been settled. FL agreed with this view. SW noted he did not need any BP 316 anchors.

11.4 Views on use of video facilities:

The meeting was judged to have worked reasonable well. Whilst it was felt to be not quite as good as a face to face meeting, people were well behaved and able to interact, though perhaps a little less than might have occurred at an ordinary meeting. (If one wanted a few words with just one person, then everyone was in on the conversation.) But it did more than offset the pain of a long journey. It

was felt on balance that having a few hubs was probably a better compromise rather than all being separately located. (No cost calculation was done on the cost effectiveness of such a set up.)

It is absolutely necessary to have at least 15 minutes pre set up time to get the software working at each location as well as the external video and conference mic / speaker systems. One cannot get more than three people around one simple built in video camera.

One location fell off line for no clear reason but was able to come back up within a few minutes. It also suffered a separate period of poor vision reception which cleared up without total loss of the signal.

It became necessary to switch off microphones at unlinked mic / speaker set ups to avoid feedback which otherwise hindered hearing the speaker. (Headphones with mics would have avoided this.) Also microphones picked up 'off meeting discussion' and amplifying them as if they were a meeting conversation.

One habit of raising hands whilst keeping the mic switched off enabled the Chair to ensure all were heard in an orderly manner. The use of thumb up or down to indicate a conclusion / vote was also of value. And having a piece of paper on which one could write a message (with a thick black pen) was useful when sound was lost with the centre! The Chair found the video of additional benefit in gauging participants' reactions over the audio based information. (Possibly because one can view several people at once but hear only one person.)

One location was illuminated by fluorescent tube which created an irritating strobe effect on back ground.

There was some difficulty with showing an item held by one person and also sharing a web location. This was possibly more due to a lack of familiarity of the tools available rather than a limitation of the system. The chair must be familiar with the software in order to get the best out of the system.

12. Date and Time of next meeting: The 20 March 2016 was selected for the date of the next meeting.

The meeting finished at 2.15pm.

Action List

Action 5A.1 FL & BM to produce a set of bullet points of key requirements for an anchor.

Action 5A.2 – NW to provide comment to SW on IC anchor training manual and then circulate amongst the committee.

Action 6.1 – NW to issue two Fischer resin applicators to SUI, DCA, CSCC & DCUC plus 2 tubes of Fischer resin to DCUC.

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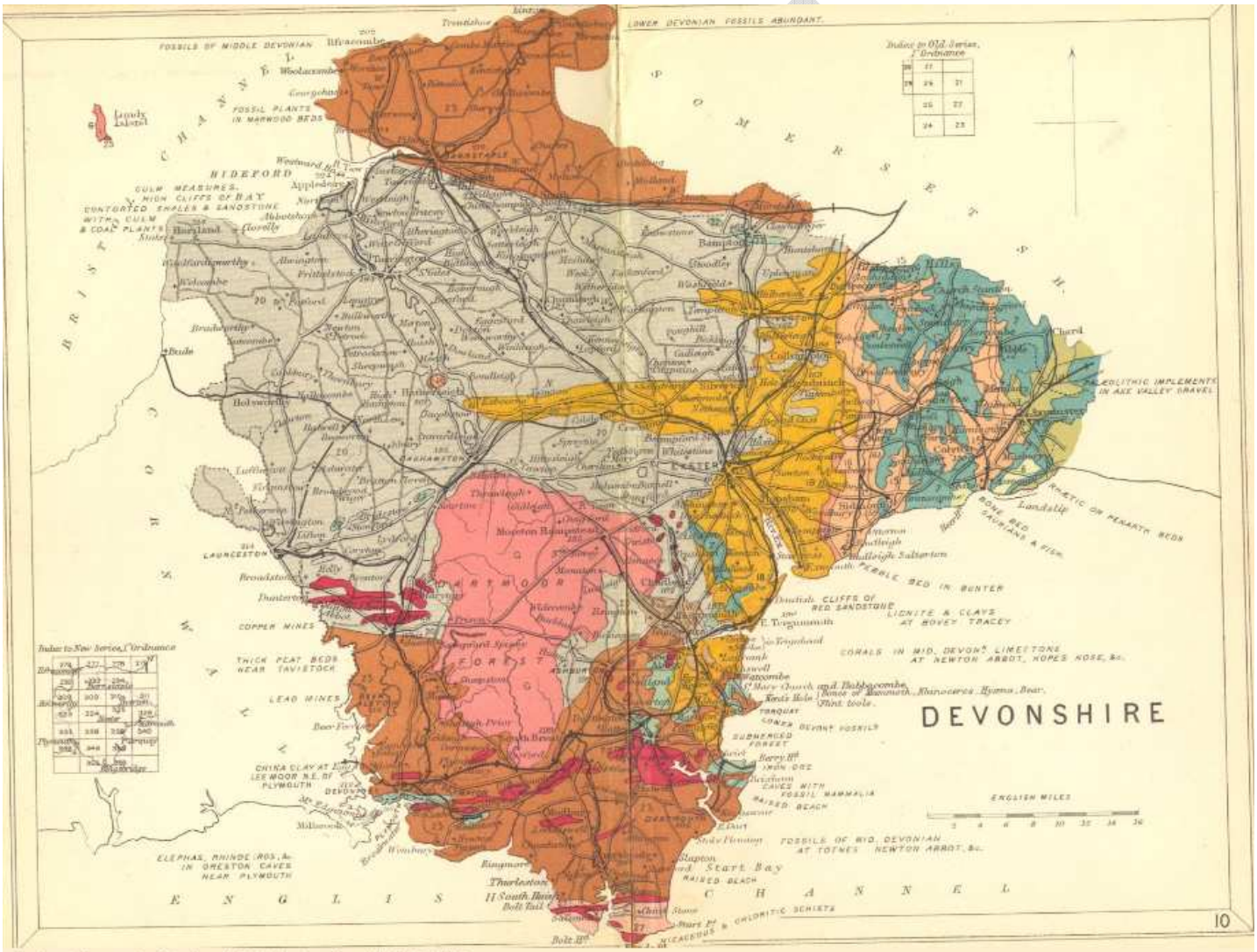
Appendix 1

Devon and Cornwall Underground Council

Resin bolting tests in rock substrates

By Richard Vooght



Geology of Devon, after Woodward (1904), based on Reynolds (1860; 1889)

Contents

Introduction

DCUC resin anchor test report for several different test sites taken place in South-West Devon during the 2014 and 2015. The tests were organised by Richard Vooght and Roger King and the assistance of the following people; Dave Warne, David Jean and Alex Heath with their help in locating suitable test sites, installation of bolts and testing of bolts being removed from the rock

Thanks have to go to the landowners Bruce and John Bolton from Chudleigh, Humphrey Walters of Great Rock and the Earl of Bedford (Tavistock woodlands) through the help of Dave Warne chairman of DCUC.

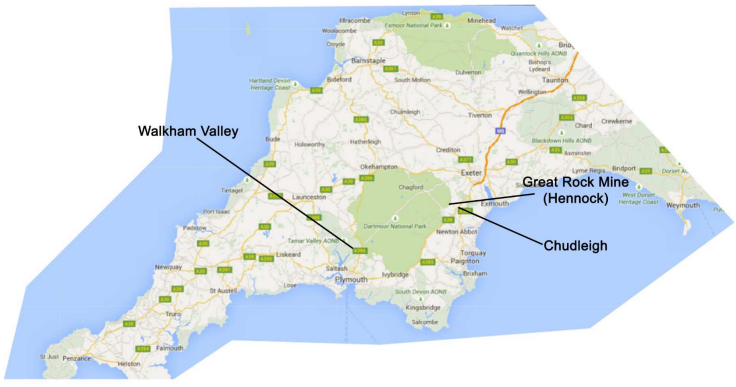


Figure 1 Map test rig of Devon and Cornwall

The system of bolts which were used varied according to the type of rocks into which they were installed these were; stainless steel 304 grade, 316 grade, HCR bolts and finally titanium bolts. The bolts were placed in by using KMR resin. All the above have been provided by the BCA (British caving Association) and they have been already provided in a variety of locations in other areas of the UK. This is for comparison with the three common rock types found in the caving and mining areas of Devon and Cornwall.

The map above shows locations of the different types of rock was tested it with the BP – bolts, these were the Walkham Valley and Devon Great Consuls both near Tavistock were tested in Killas, Great

Rock Mine near Hennock was tested in Granite, and at Chudleigh Rock Centre to test Chercombe bridge Limestone which is a type of Devonian Limestone.

Devonian Limestone

There are three main types of Devonian Limestone's within Devon which were formed in the middle Devonian age (393 – 383 million of years before present). The three main areas where this type are Limestone is found is from Chudleigh down to the Buckfastleigh area this is known as Chercombe Bridge Limestone, Torquay and Brixham this is known as Torbay Limestone and finally Plymouth and Yealmpton which is known as Plymouth Limestone. All the Limestones were formed in a coral reef and coral island structure, where areas like Torbay and Plymouth were coral reefs and areas like Chudleigh and Brixham were coral islands.

Chercombe Bridge Limestone

Chercombe Bridge Limestone is predominantly dark grey with some medium grey well bedded Limestone formed in the middle to upper Devonian age.

Dartmoor Granite

Dartmoor Granite formed from a plutonic intrusion and slowly solidified under a layer impermeable of rock and rarely erupted more than a small fraction of the magma within the intrusion so there are a number of dykes around Dartmoor where it is shown that igneous activity had reached the surface of the crust. The Granite is made of a matrix of minerals; most obvious are the large white crystals which are Phenocrysts of feldspar and small crystals of quartz and mica, however some varieties of Granite on Dartmoor do not have Phenocrysts of feldspar crystals.

The Dartmoor Granite is connected at depth the other Granite masses of Cornwall forming a large Granite intrusion called a batholith. Dartmoor Granite was formed approximately 300 million years ago within the late Carboniferous and early Permian Periods. When the Dartmoor Granite was forming it metamorphosed the country rock around it. When it was cooling the residual fluids and gases condensed and crystallised in a hydrothermal process to form an economically valuable mineralisation of tin, copper, iron and lead which then led to a multiple amount of mines around and within the area around the Dartmoor Granite. A rich deposit of china clay (Kaolin) was worked on a large scale on the southern edge of Dartmoor near Ivybridge.

There is a likelihood within the mines in Granite that there may be patches of Kaolinised Granite which is very unstable, care must be taken as sometimes the Kaolinised Granite has a harder layer within the passage as it's been exposed to the air but within a short distance the Granite is very soft so bolting in an area of Kaolinised Granite should be taken with care or avoided if possible.

Killas

Killas is a Cornish mining term for metamorphic rock strata of sedimentary origin which were altered by the heat from the intruded Granites form Devon and Cornwall. It is formed in the middle to late Devonian era and is a type of mudstone. It ranges as different metamorphic types from basic

mudstone through to hard metamorphic rock like Delabole slate where this is been used for hundreds of years as roofing slates. The Killas underlies two thirds on and around Dartmoor in Devon and as a result of hydrothermal metallisation from the Granites contain a majority mineral loads and veins and again a multiple amount of mines are found in it.

Anchor testing

Devonian Limestone: Chercombe bridge Limestone summer 2014

The first anchor test taken in Devonian Limestone was taken out in the summer 2014. The site was at Chudleigh in gardens of the Rock house on the north side of the main Limestone outcrop this is a disused quarry. This was on a small exposure by the camping area. Grid reference NGR SX 86443 78787

Four anchors were initially placed when they were extracted one failed at a low level. This was the first one placed and it would seem that the resin had not mixed properly. Another bolt was placed in an undamaged hole and extracted later. The resin used was the last of the tube and did not mix properly; the resin was a granular texture. All the bolts installed in this initial test were BP 304 stainless steel bolts. The rock didn't fail, the hole was clean and didn't show any damage or any coning.

Serial number	force	Comments
558	33.10 kN	No damage to rock
557	32.80 kN	No damage to rock
559	18.00 kN	No damage to rock
556	26.40 kN	No damage to rock
551	8.00 KN	See above

Table 1 Test results of resin anchor bolts in Devonian Limestone: Chercombe Bridge Limestone Summer 2014

Dartmoor Granite

The site was on the launder level of the Great Rock mine complex and was taken out in the summer 2014. This was on a boulder on the side of the track in the mine complex. Grid reference NGR SX 81976 81868

Four anchors were installed to bolts which when pulled produced no damage to the rock, one bolt when pulled produced spalling around the hole and another cracked the boulder on extraction and also produced spalling around the hole as well. All the bolts installed were BP 304 stainless steel bolts.

Serial number	force	Comments
555	31.30 kN	No damage to rock
554	25.30 kN	No damage to rock
553	31.50 kN	Boulder cracked on extraction and some spalling.
552	32.50 KN	Spalling around hole

Table 2 Results of resin anchors which were pulled from Dartmoor Granite

Killas

The initial test in Killas was in the summer 2014 and was on the site of the Devon Great Consul's complex. This was in the adit entrance to Wheal Fanny. The initial test was a failure but this was

included in this report to document the bolts used. One bolt was placed on a shelf in the entrance to the adit the remaining were placed on a boulder which all had coning on them. The bolts which were placed in the boulder produced a low reading, this was because the boulder was poorly selected and de-laminated due to its size and where it was found so was likely to have weathering affecting it. One bolt (560) was a BP 304 stainless steel bolt be others were BP 316 stainless steel bolts.

Serial number	force	Comments
560	20.08 KN	Cracking around bolt
321 (316)	12.80 kN	Cracking around bolt
323 (316)	12.90 kN	Cracking around bolt
328 (316)	13.45 kN	Cracking around bolt

Table 3 Test results from resin anchors pulled from Killas: Devon Great Consuls

Devonian limestone: Chercombe Bridge Limestone Summer 2015

This was the second test done in this type of Limestone. This was to test two different types of bolts; first were titanium bolts and second was to test HCR bolts supplied by Bolt Products, a total of four bolts were installed. The site was in that the same place as the initial test pull was made in 2014 (see above). The bolts were placed on an outcrop limestone in the Chudleigh Rock Garden. There was a mixed result between both bolts in a result that the titanium bolt of which one was installed was pulled at 17.83 kN and broke the bolt where it was resined into the rock. However the HCR bolts when pulled peaked at a high force averaging 60 kN which was three times the pass rate of 20 kN.

With regards of the titanium bolt installed and broke at the eye of the bolt at 17.83 kN.

Bolt	Head starts to Distort	Notable crack (sound)	Peak	Comments
Titanium bolt	17.83 kN		17.83 kN	Bolt broke when pulling see note above
HCR one	10.69 Kn	63.76 kN	63.76 kN	Minor coning was noticed
HCR two	12.62 kN		58.19 kN	No damage
HCR three	11.93 kN	62.03 kN	62.03 kN	Minor coning was noticed

Table 4 Table of results of resin anchors pulled from Devonian limestone: Chercombe Bridge Limestone 2015

Killas: Walkham summer 2015

This round of testing was carried out in the Walkham Valley on the River Tavy. Six anchors have been placed in the ground cut out of the hillside exposing the country rock beside the Walkham United mine adit (grid reference NGR SX 49035 70815), these anchors being placed horizontally into vertical rock face, all bolts were installed in a good competent rock. It was noted that some of the anchors appeared to unscrew from the resin in line with the twist of the wire when under stress. There was little damage to the rock apart from some slight surface delaminated; the anchors mainly pulled clear from the holes. There was two types of bolt installed three were BP 304 stainless steel bolts and three bolts were BP 316 stainless steel bolts.

Serial number	Type of bolt	Date installed	Date pulled	Head starts to Distort	Resin audible cracking	Peak force

54	304	28 April 2015	10 July 2015	14.5 kN	33.5 kN	43 kN
55	304	28 April 2015	10 July 2015		28 kN	30.4 kN
51	304	28 April 2015	10 July 2015	10 kN	28 kN	44 kN
326	316	28 April 2015	10 July 2015	11 kN	35 kN	42 kN
320	316	28 April 2015	10 July 2015	9 kN		37 kN
330	316	28 April 2015	10 July 2015	9.8 kN	23 kN	37.85 kN

Table 5 Test results of resin anchor bolts in Killas: Walkham Valley Summer 2015

Conclusion

Thanks have to go to all the people who assisted in this report also to the landowners who made it is possible to complete the tests. In future, if it is possible to get permission or find a location then it would be beneficial if test rigs were placed in Devonian limestone in the Plymouth area and also in the Torbay area, as these differ to one another as they have a slightly different chemical structure to the Devonian limestone which was tested, also where some caves are located they are close to the sea for example Berry head near Brixham some bolts would be exposed to seawater so this may affect both resin and bolt. Hopefully the titanium bolts with permission from BCA would be acceptable for this job. In the result above it would be interesting to see how the HCR bolt performs in both Killas and granite.

References

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