

Bolt testing in slate

A cautionary note: The following results relate to the bond between varieties of bolts in a single block of good quality slate. Selecting a good quality piece of rock appropriate to bolt can be very difficult, particularly given that the rock has been quarried. There is also anecdotal evidence of slate cracking due to the placement of a bolt (after all this is how quarrymen would have split the rock!)

Continuation of the testing first done with a Hydraclaw test rig on a series of bolts in February 2012. Most of the bolts were placed on the 1st of Feb 2012 in a large sound looking block of slate at lake level adit within Cwmorthin Mine/Quarry, some additional bolt were placed following the first round of tests, and 2 more on the day of the second test.

Follow up testing on the 23rd of June with the BCAs testing rig, which is capable of exceeding the 20kN (20kN was the maximum range of the Hydraclaw rig). Also the BCA rigs feet are further apart providing a better chance to test the rock within the bolts "cone" as well as the bolt/rock bond. The second round of tests pulled all bolts to destruction.

Bolt Number	Bolt Type	Bolt description	Date Placed	Test to 20kN, February 2012		Test to destruction, June 2013
				Observations at 6kN	Observations beyond 6kN	Observations
1	Petzl 10mm Colinox with Spit Maxima M10 ampule resin	12mm hole drilled to 70mm, cleaned by air pump and stiff brush. Resin ampule inserted and cracked with the bolt. Bolt twisted over 10 times to mix resin and left to set.	1/2/12	No visible change	Some deformation at 10kN. Gauge slipping (suspect deformation of the anchor) at 11-12kN. Taken to 20kN. Bolt visibly deformed (egg shaped)	Test initiated quickly (didn't get a chance to see much!) although resin failed at 32kN. Top section of rock cracked.
2	Petzl 10mm Colinox with Spit Maxima M10 ampule resin	12mm hole drilled to 70mm, cleaned by air pump and stiff brush. Resin ampule inserted and cracked with the bolt. Bolt twisted over 10 times to mix resin and left to set.	1/2/12	As previous bolt	As previous bolt	Resin failed at 30.5kN. Hanger deforming at 15kN (although significantly deformed from previous test). Dropped from 10-2kN as bolt pulled from the rock.
3	Petzl 12mm Goujon (expansion) bolt with Couer (steel) hanger	12mm hole drilled over 70mm, cleaned with pump and stiff brush. Bolt hammered into place and tightened as much as possible with a short spanner	1/2/12	Plate lifted slightly from the rock at 5-6kN.	Hanger deformed at 23kN and plate lifted further at 15kN. Bolt held at 20kN although some slippage of the gauge. On removing the testing rig the hanger was loose on the bolt	Plate lifting around 3-4kN, 12kN+ hanger starts to deform and continues to deform until hanger snapped at 38.4kN
4	Petzl 12mm Goujon (expansion) bolt with Couer (steel) hanger	12mm hole drilled over 70mm, cleaned with pump and stiff brush. Bolt hammered into place and tightened as much as possible with a short spanner	1/2/12	As per previous bolt	As per previous bolt	Plate lifting from 3kN again, cracking noises at 11kN and hanger starts to deform. Hanger continues to deform snapping at 37.1kN
5	Spit Rock Screws 145mm M10	8mm hole drilled and cleaned with pump. Coeur hanger placed on bolt and bolt screwed into place	1/2/12	No visible change	Plate lifted at 9kN, cracking noises around 12-13kN, head of bolt snapped off at 17kN	Failed on previous test

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6	Spit Rock Screws 145mm M10	8mm hole drilled and cleaned with pump. Coeur hanger placed on bolt and bolt screwed into place	1/2/12	As per previous bolt	As per previous bolt with the bolt head snapping at 18kN	Failed on previous test
7	Screwfix M10 Fisher FSA Sleeve Anchor 70mm	10mm hole drilled and cleaned with pump. Sleeve anchor hammered in and bolt tightened, with Coeur hanger plate fitted, with a spanner	1/2/12	No visible change	Plate lifted at 9kN, held at 20kN with little visible change. On removing rig the hanger rattled loose on the thread, hanger was difficult to remove and the thread visibly bent	Bolt looked bent from previous test, started to move almost as soon as a load placed on it. Bolt continued to bend and failed (head of the bolt sheered off) at 13.5kN
8	Screwfix M10 Fisher FSA Sleeve Anchor 70mm	10mm hole drilled and cleaned with pump. Sleeve anchor hammered in and bolt tightened, with Coeur hanger plate fitted, with a spanner	1/2/12	As per previous bolt	As per previous bolt	Again bolt looked bent at the start of the test (from previous testing). Started to bend at 1kN, bolt head sheered off at 11.2kN
9	Multi Monti 100mm x 8mm rock screws	8mm hole drilled and pumped clean. Bolt screwed into place with a Couer hanger fixed	1/2/12	No visible change	Plate lifted slightly around 9kN but no other visible deformation	Hanger loose on bolt (suspect the hole was not deep enough when initially placed). Hanger soon lifted and started to deform around 14kN. Head of the screw sheered off at 25kN following sever deformation of the hanger.
10	Multi Monti 100mm x 8mm rock screws	8mm hole drilled and pumped clean. Bolt screwed into place with a Couer hanger fixed. Unable to screw the bolt in completely, thread snagged on something	1/2/12	As per previous bolt	Hanger lifted as it was loose, no other obvious deformation	Hanger started to bend at 3kN, and continued to deform throughout test. Some cracking noises from 13kN and loader prior to the bolt sheering below the bolt head at 24.9kN
11	8mm Spit with aluminium hanger	Drilled with mechanical drill and finished by hand	1/2/12	Plate visibly deformed as soon as a load was placed on the hanger	Difficult to get to 6kN as the plate kept bending. Hanger settled at 8kN, radically deformed, and continued to 11kN where the limit of the testing rigs range was reached. Hanger visibly loose once load released.	New hangers placed for this test, using a ring hanger rather than a plate. Hangers started to deform at 2kN and continued throughout the test. Bolt started to lift at 10kN. Rock failed at 14kN-15kN with a chunk of rock lifting with the bolt
12	8mm Spit with aluminium hanger	Hand drilled	1/2/12	As per previous bolt	Early deformation as per previous bolt however managed to take the bolt to 20kN. Hanger visibly loose once load removed	Again a ring hanger used instead of the plate. Ring stated to distort at 2-3kN and continued to distort throughout test until the ring snapped at 20.5kN
13	B & Q 16mm M10	16mm hole drilled and cleaned with pump and stiff brush. Bolt with Couer hanged fitted hammered into the hole. Nut tightened with a spanner	1/2/12	Sleeve of the bolt proud of the rock at 6kN	Thread visibly bent at 7kN and lifting at 10kN. Taken to 20kN. On removing the load hanger loose.	Bolt loose from previous test. Belt almost strait away as load pulled, continued to distort noticeably around 7kN. Continued to bend and pull out from 10kN. Hovered around 12-14kN as it lifted out.
14	B & Q 16mm M10	16mm hole drilled and cleaned with pump and stiff brush. Bolt with Couer hanged fitted hammered into the hole. Nut tightened with a	1/2/12	As previous bolt	As previous bolt	Loose bolt head from start. Bolt flexed and belt almost strait away. Started to lift from the rock at 14kN. Lifted from 16-23kN with the nut sheering off at 23kN

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		spanner				
15	Multi Monti 100mm x 10mm	Not placed				
16	Multi Monti 100mm x 10mm					
17	Multi Monti 100mm x 6mm					
18	Multi Monti 100mm x 6mm					
19	Petzl 10mm Colinox with Spit Maxima M10 ampule resin	Places in the side of the block	1/2/12		As previous bolt	Noticeable deformation around 26kN with the resin bond failing at 29kN
CRO 1 (used hole 15)	Raumer Hang Fix M10XL	10mm hole drilled to 120mm. Hole pumped clean. Bolt hammered in and nut tightened as much as possible with a short spanner	4/3/13	Not tested		Plate started to lift almost strait away (0.6kN) but significantly from 5kN to 7kN. Dropped at 8.1kN to 7.9kN suggesting slippage, then at 9kN noticeably pulling out maintaining a load of around 8kN as it pulled out, dropping as low as 3.5kN and up to 8.5kN as it pulled, out
CRO 2	Raumer Hang Fix M10XL	10mm hole drilled to 120mm. Hole pumped. Bolt hammered in and nut tightened as much as possible with a short spanner	4/3/12	Not tested		Plate hanger bending and lifting from 3kN. Bolt lifting from 7kN Clearing pulling out at 9kN. Hovered around 9-13kN as the bolt pulled out. Top of the bolt clearly bent as the bolt pulled out.
CRO 3	Raumer Hang Fix M10XL	10mm hole drilled to 120mm. Hole pumped. Bolt hammered in and nut tightened as much as possible with a short spanner	23/6/13	Not tested		Plate hanger lifting from 3kN with the bolt pulling out from 4kN. Hovered around 5-7kN as the bolt pulled out. As about half the bolt is out it seemed to grab something holding, with the head of the hanger snapping off at 10kN (leverage?)
20	Petzl 12mm Goujon (expansion) bolt with Couer (steel) hanger	12mm hole drilled over 70mm, cleaned with pump and stiff brush. Bolt hammered into place and tightened as much as possible with a short spanner	23/6/13	Not tested		Plate lifting and distorting from 7kN, with the bolt pulling out (slightly) from around 11kN, clearly lifting from 14kN. Rock cracks and fails at 19kN-20.5kN, large "plate" of rock lifted with the bolt.

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