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# Strength Characteristics of Secura Hollow Groutable Cable Bolts

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# STRENGTH CHARACTERISTICS OF SECURA HOLLOW GROUTABLE CABLE BOLTS

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*ABSTRACT*: The strength properties of Secura Hollow Groutable Cable-bolts (HGC) were examined for tensile and shear failures. The 30 mm diameter, nine strand, cable bolt consisted of a mixture of five 7.5 mm plain and four 7.0 mm indented strands wrapped around a central 14 mm steel grouting hole to make a round cable with lay length of 500 mm with bulbs at 500mm centres of diameter 35mm. The tensile strength of the cable was tested in accordance with the British Standard (BS7861-part 2:2009) using the double embedment pull test. The shear strength of the cable bolt was tested by both the BS7861 single and UOW double shear methods. The single shear double test used a guillotine shear frame of double embodiment tendon/grout assembly in a steel tube, while the double shear method enabled shear testing of the cable bolt in concrete to simulate rock. It was found that the tensile strength of the cable was in the order of 680 kN, the shear load by single shear test, based on the average of three tests, was around 448 kN. The shear failure load of the cable bolt from double shear testing based on two tests averaged around 786 kN which is significantly higher than achieved from the single shear test. Thus the shear value, obtained from the double shear method was between 13 and 18 % greater than the single shear test method. The use of the guillotine shear frame for the single shear method was considered an unrealistic method of evaluating the shear characteristics of the cable bolts in rock.

## INTRODUCTION

Australia uses a variety of cable bolts as a secondary system of support for strata reinforcement. The use of cable bolts initially began in metalliferous mines in mid-1960 and was later introduced to underground coal mines by the early 1970's. Initially, cable bolts were of a conventional 7 single wire strand round cable and soon other cable types of different strand configurations followed. Presently, there are a variety of cable bolts which vary in size, structural formation, and strength to suit different ground stratification and conditions.

In general, installed cable bolts in situ are subjected to complex ground forces, which range from axial loading, to shearing and unwinding leading to the loss of encapsulation. The variation of the various loading force categories is dependent of the changes in ground conditions. Accordingly, methods used to evaluate the cable bolt strength characteristics should embrace various factors that influence the competency of the cable bolt in providing the necessary reactions to the prevailing ground forces. Thus, the forces applied on the cable bolt for strength evaluation tests must simulate the ground forces that the cable element is subjected to in situ.

The strength performance of cables bolts is currently based on both pull and shear tests. Thomas (2012) documented a total of 19 cable bolts, which were subjected for load transfer studies by pull testing. Few of these cables have since being tested in shear in addition to pull testing studies. Testing in shear has been carried out in accordance to British Standard (BS7861-Parts 2: 2009) for strata reinforcement support system components (Figure 1). The British Standard for both Pull and shear tests are normally carried out in embedment tubes with an internal diameter equal to the size of the hole as recommended by the manufacturer for tendon installation and with the steel tube wall thickness of at least 10 mm. The internal surface of the tubes is threaded to a 2 mm pitch and 1 mm deep to maintain bonding of the resin / grout between and steel wall. One notable reported investigation using the British Standard of shear testing was carried out by Rock Mechanics Technology (RMT) on the mechanical performance tests on Megastrand flexible bolts (Clifford, 2002) Cementitious and resin based grouts were used for these tests, depending on the type of tested cable in steel tube.

Craig and Aziz (2010 a and b) and later on by Aziz *et al.,* (2014 a,b) have evaluated the shear strength of cable bolts by double shear testing in concrete to simulate rock formation. Testing of cable bolts in

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concrete was considered a rational method of simulating cable shear failure *in situ*, particularly where the sheared cable occurs without bed separation and sagging.

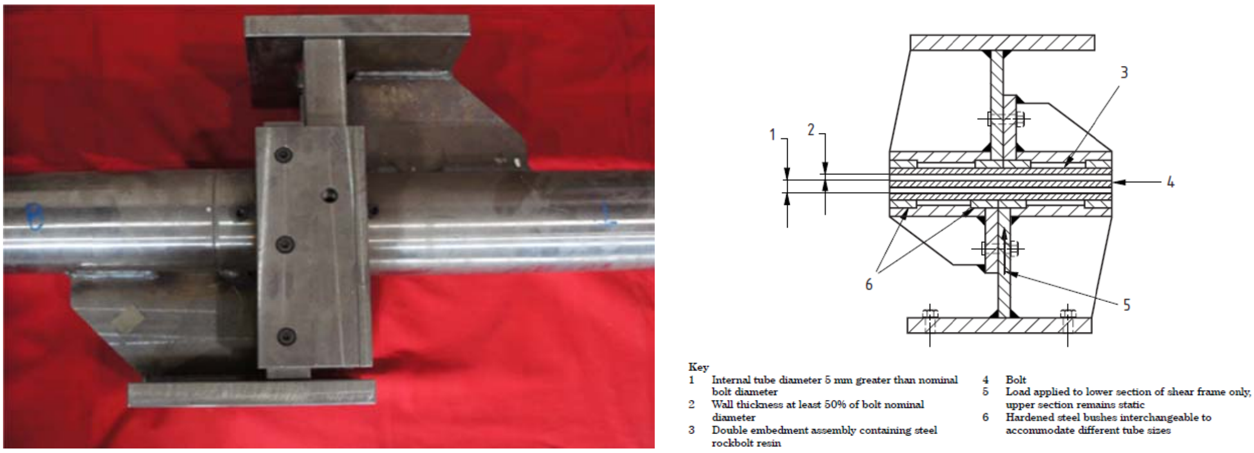


**Figure 1: Single shear frame for testing of cable bolt (BS7861- part 2: 2009)**

In this paper a newly marketed cable bolt known as Secura HGC-bolt has been studied for load transfer capability and performance. The cable bolt was tested for tensile and shear failures in the laboratory. In particular the performance of the cable for shear failure was carried out using the BS standard of double embedment tube as shown in Figure 1 and by the double shearing method in concrete blocks as reported by Graig and Aziz (2010 a,b). A particular emphasis has been given to the variations in shear strength performance of the cable bolt by both methods of testing.

## CABLE BOLT DESCRIPTION

Secura HGC is the latest type of cable bolt that is currently undergoing trials in Australian mines and soon to be marketed by Orica Pty Ltd. Structurally, the cable bolt consists of a mixture of five plain and four indented single wire strands laid around central 14 mm dia. hollow grout tube. The plain wire strand is 7.5 mm in diameter and the indent wire strand is a 7 mm (7.5mm on largest cross section and 6.7mm on smallest cross section). The completely laid mixed strands will, therefore have two plain wire strands side by side as shown in Figure 1. The indented spiral pitch of the strand in the order of 40 mm however, the cable strand lay length, in general, is in the order of 500 mm. The cable bolt is bulbed type with the bulbs set at 500 mm spacing. The tensile strength of the cable is in the order of 69 t. Table 1 shows the specifications of both plain and indented wire strands. Clearly there is a variation in strength loss of around 11.85 % between plain and spiral strands as shown in Figure 2, which corresponds to a cross section area reduction of 12.9 %. The shear characteristics of the Secura HGC cable bolts were evaluated by both single and double shear tests

**Table 1: Cable strands specification**

| Type | Diameter (mm) | Cross section Area (mm2) | Rib width (mm) | Pitch length (mm) | Failure load (kN) | Variation in cross section area (%) | Variation in failure load |
|---|---|---|---|---|---|---|---|
| Plain | 7.5 | 44.2 | 1.8-2.2 | 35-45 | 75.08 | *12.9* | *11.85* |
| Spiral | 7.0 | 38.5 | - | - | 67.12 | - | - |

## TENSILE STRENGTH TESTING OF CABLE BOLT

The tensile failure testing of the cable bolt was carried out in accordance to the British Standard (BS7861-Parts 2: 2009) and was carried out by ALS Australia Pty Ltd, NSW (ALS Report, 2014). The grouted hollow cable samples were held between the two jaws of the universal tensile tester a laser distance reader was used to measure movement of the platens of the testing machine (refer to Figure 4a for test set up). The samples were encapsulated in the embodiment tubes with FB400 Orica Grout. A tensile load was exerted using a ram travel speed of approximately 5 mm per minute. The displacement was recorded at regular load intervals of 50 kN until the maximum load was achieved. This was repeated with two other grouted hollow cable samples. The average failure load of the cable bolt was 679 KN (68 t) and Figure 4b shows the snapped faces of the cut strands of the cable, which clearly indicate the failed section of the cable in tension. Figure 5 shows the load-displacement profiles of three pull tested SHGC cable bolt sections.

**Figure 2: Secura hollow groutable cable bolt**

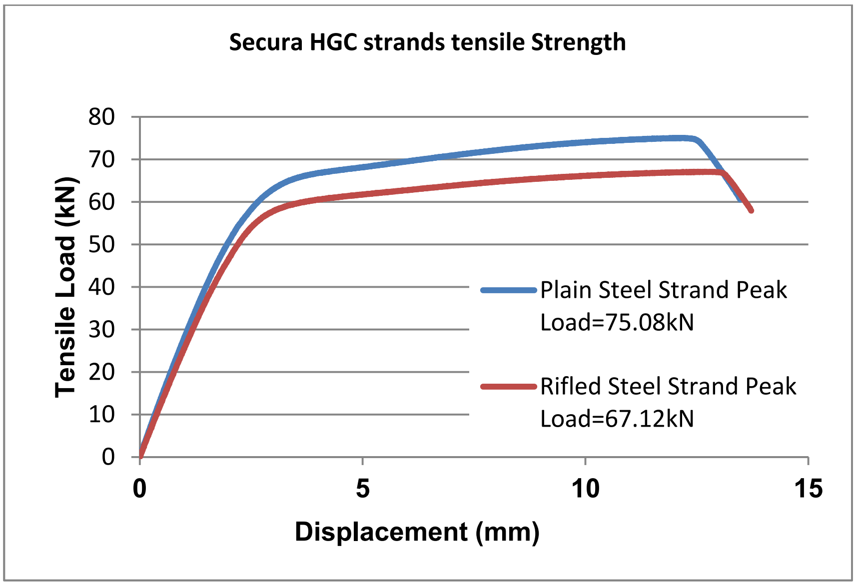


**Figure 3: Load displacement graphs of both plain AND INDENT strands of the SHGC**

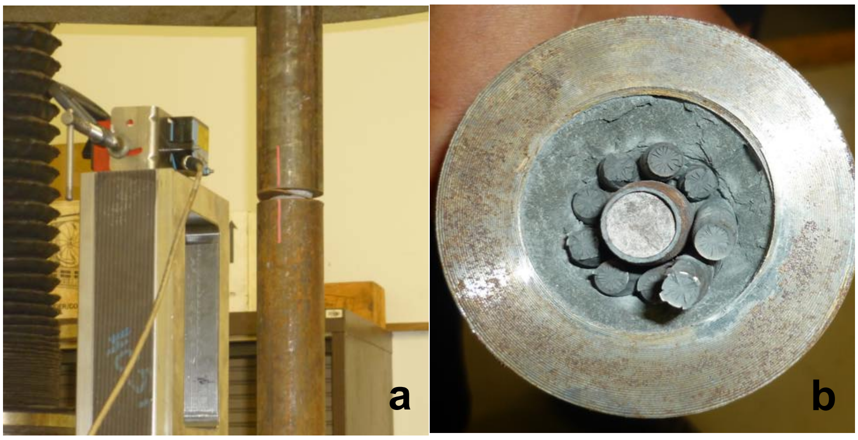


**Figure4: (a) Tensile pull test set up and (b) snapped section of the cable bolt**

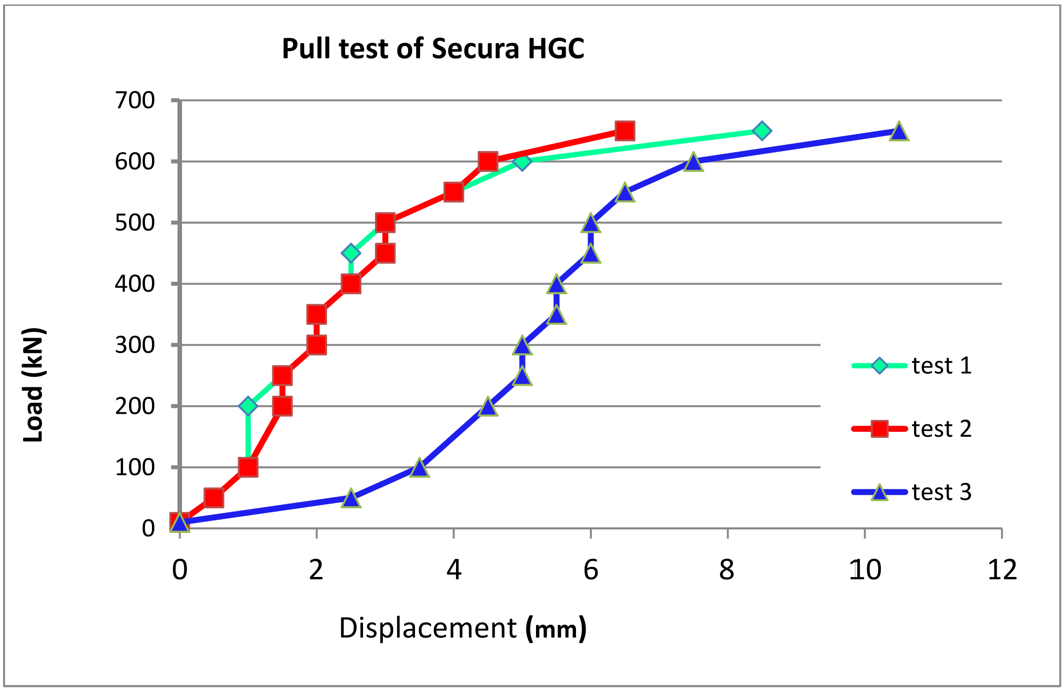


**Figure 5: Load displacement profiles of three pull tested Secura HGC cable bolt sections**

## SHEAR TESTING

### Single shear test

Three more samples grouted in the double embedment tubes were tested for shear. The grouted hollow cable samples were positioned into the specifically designed shear testing jig and placed between the two platens of the universal tensile tester a laser distance reader was used to measure movement of the platens of the testing machine (refer to Figure 6a for test set up). A shear load via a compression load on the jig was exerted using a ram travel speed of approximately 2.5 mm per minute. A preload of 10 kN was applied to the sample and the initial displacement was then measured. The displacement was recorded at regular load intervals of 50 kN until the maximum load was achieved. This was repeated with two other grouted hollow cable samples.

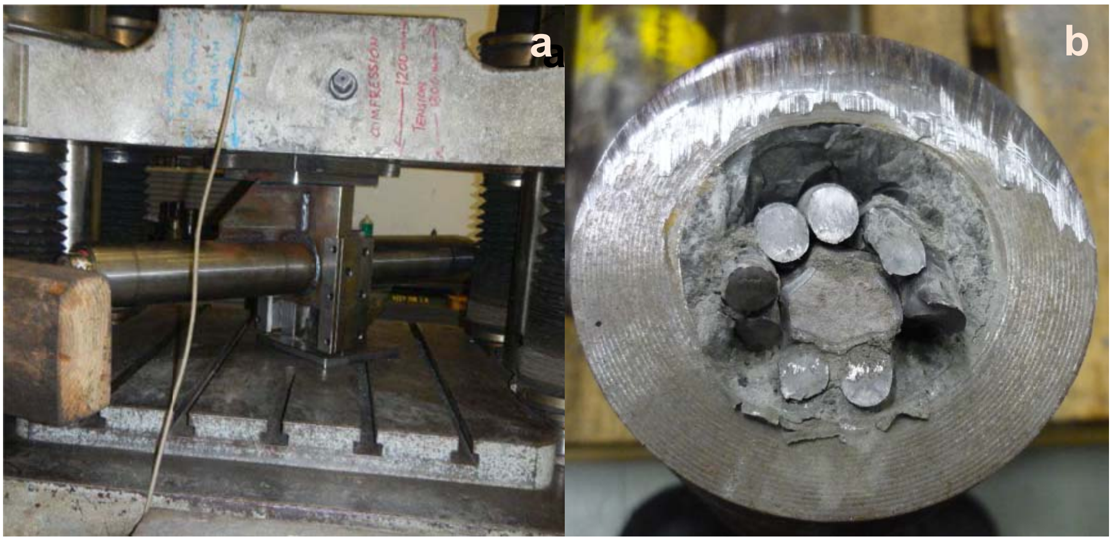


**Figure 6: Shear test and a view of the sheared sample. Note the interaction between the strands and the steel tube**

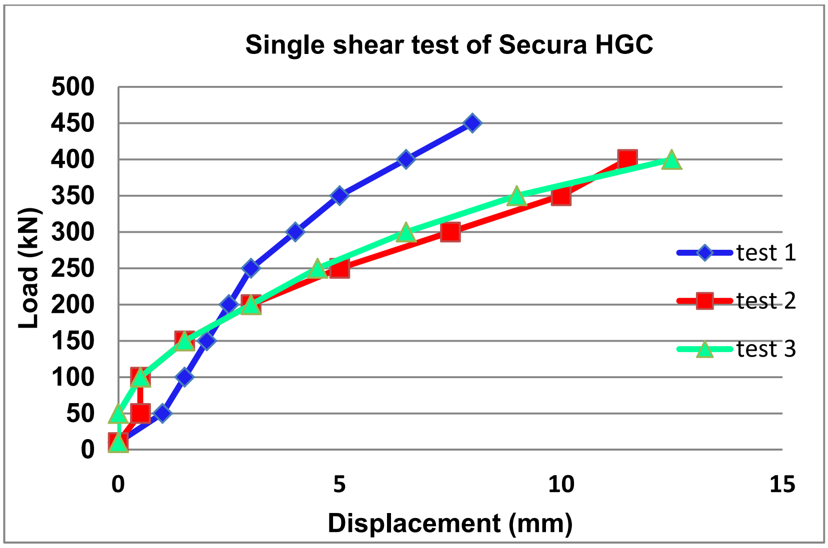


**Figure 7: Load-displacement graphs of single shear tests**

**Double shear testing**

Two double shear tests were carried out on SHGC cable bolts. The procedure used for casting concrete blocks was the same as described by Aziz *et al.,* (2014). The UCS value of the concrete was 40 MPa, determined from testing 100 mm diameter cylindrical concrete samples. The first cable bolt was installed in the concrete blocks using FB400 grout and the second was encapsulated with a two component pumpable resin Carbothix (Meikle *et al.,* 2013). The position of birdcages in respect to the shear planes are illustrated in Figure 8. One 60 t load cell was mounted on each protruding side of the assembled concrete blocks and tensioned to the predetermined axial pretension load, using a "Blue Healer" tensioner. Tensioning of the cable was retained by the barrel and wedge retainer. This was followed by the injection of the grout in the central concrete blocks hole for bolt encapsulation. Grouting of the cable in the concrete block was achieved via 20 mm diameter holes drilled on top of each concrete block as shown in Figure 8.

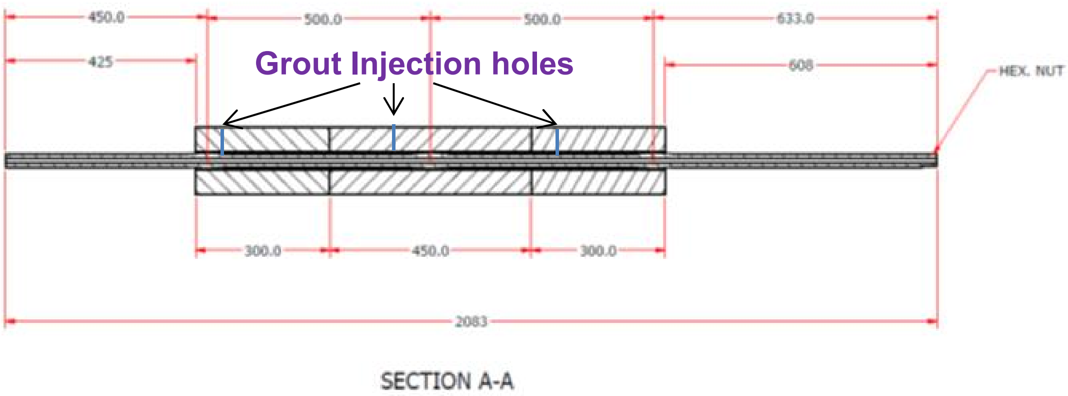


**Figure 8: Cross section of double shear blocks and cable**

After seven days of grout/resin curing time, the double shear assembly was then placed on the carrier base frame consisting of a parallel pair of rail track sections welded to a 35 mm thick steel plate. The outer side 300 mm3 cube blocks of the double shear apparatus was mounted on 100 mm steel blocks, leaving the central 450 mm long block free to be vertically sheared down a diameter of up to 100 mm as shown in Figure 9.

The process of double shear testing consisted of loading the central block vertically in the 500 t compression testing machine. The 450 mm long middle section of the double shear apparatus was then vertically shear loaded at the rate of 1 mm/min for the maximum 100 mm vertical displacement. The rate of loading and displacement was monitored and simultaneously displayed visually on a PC monitor. Cables and blocks were then dismantled and manually split open after shear testing was complete. An example of post-test broken cable and blocks are shown in Figure 10.

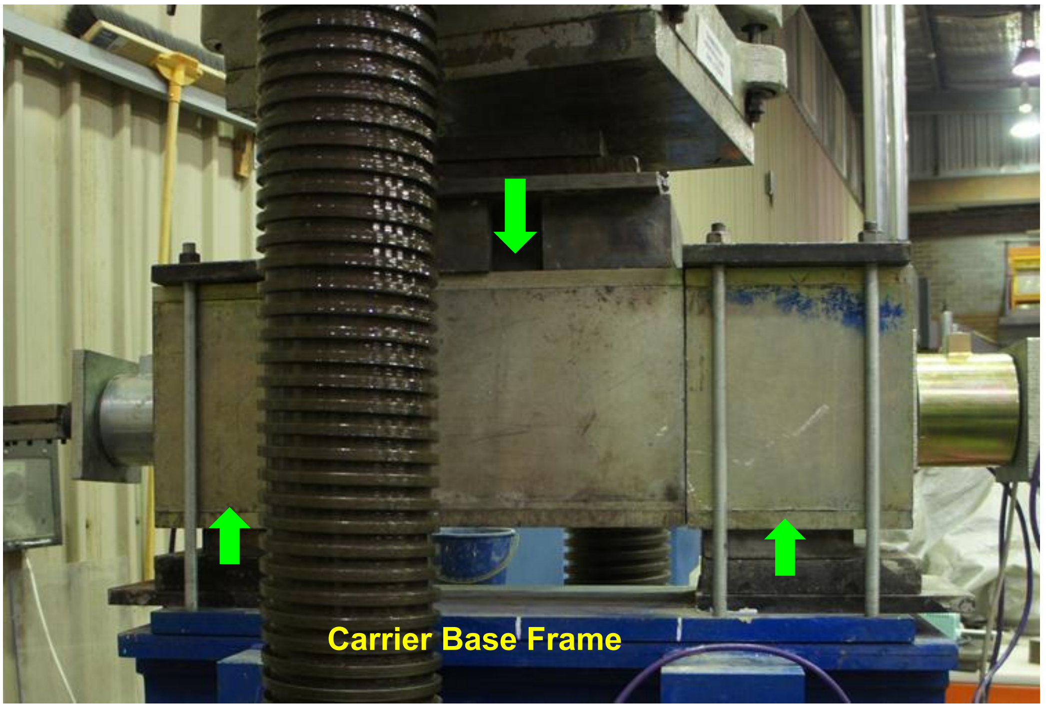


**Figure 9: Double shear cable and concrete blocks assembly**

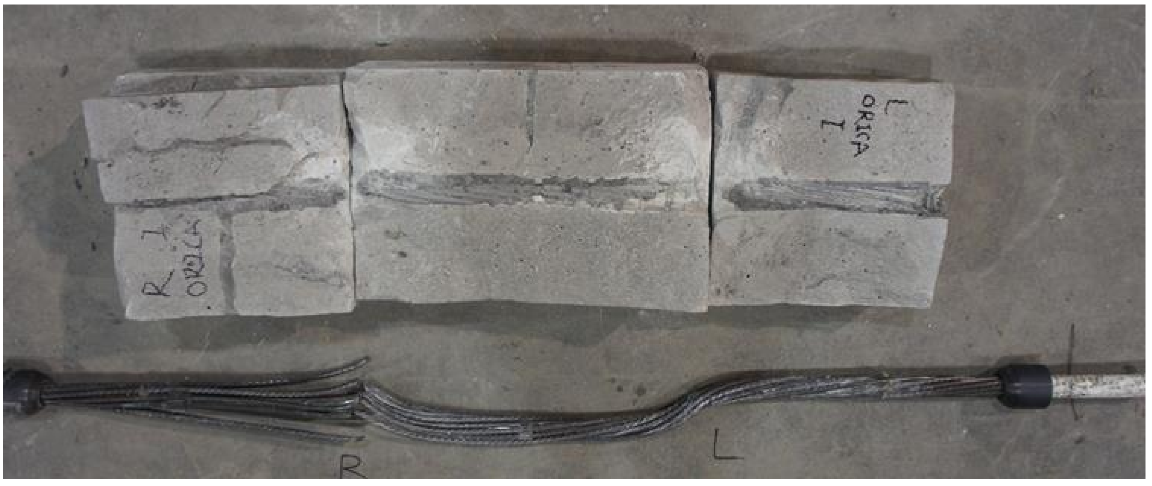

**Figure 10: Post-test dismantled cable double shear assembly**

## RESULTS AND DISCUSSION

Table 2 shows both single and double shear test results of the Secura HGC cables. Figure 11 shows the combined shear and axial pretension load of each tested cables. The average test result of single shear guillotine shear test was carried out independently and in accordance with the British Standard BS 7861-Part 1 [ALS Report No 27244248-1, May 15, 2014]. However, the highest shear load on each joint face obtained from the double shear test was 800 kN with the cable being grouted with FB400 cementitious grout, which is pretensioned to an axial load of 270 kN. The second double face shear test yielded 772 kN. The second test was encapsulated with Carbothix and loaded axially to 97 kN.

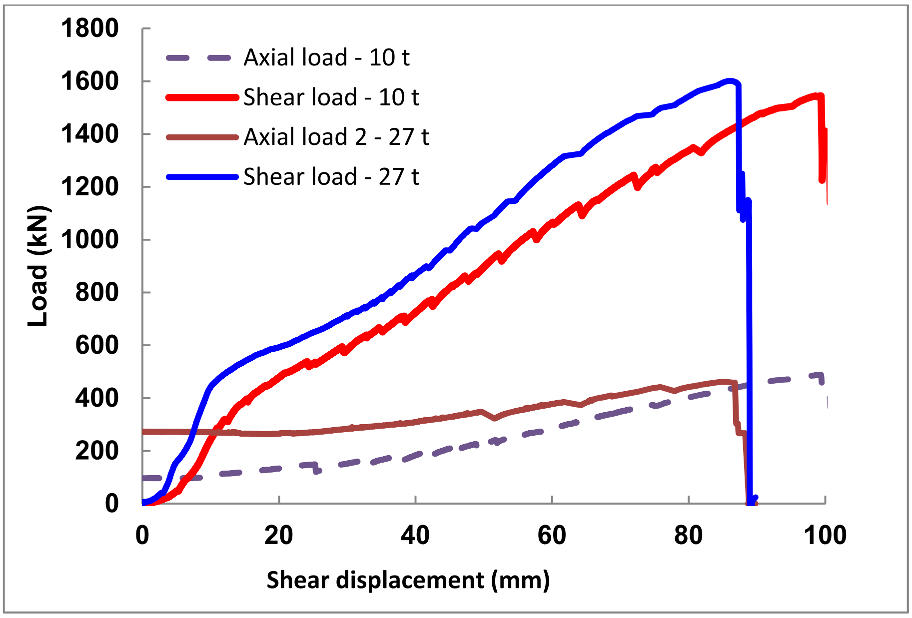


**Figure 11: Load-displacement graphs of shear loads together with two shear tests at 10 and 27 t initial axial loads**

The relatively lower shear force due to single shear testing can be attributed to; (a) the cable being sheared at zero pretension and (b) the cable being subjected to the guillotine effect, with cable strands being damaged by the steel tube wall. This damage is clearly visible from the post shear view of the cable cut in Figure 6. The shear load per side for each double shear cable bolt was significantly higher than results of testing cables in the single guillotine shear test. These increases were 18 and 13 % respectively. Also, testing by double shearing method may require some portion of the shear force to overcome the shearing forces of the concrete surfaces of joint planes. This level of joint surface shear is dependent on the cable pretension. Currently, two methods are investigated to define the shear component of the concrete faces or eliminate it completely, in a manner similar to the cable being sheared across separated bedding planes with no contacts. No cable rotation or unwinding was observed during shear testing.

The shear failure load of the cable was influenced by the strength loss of the indented strand (about 11%) of the cable as demonstrated by the load displacement profiles shown of Figure 3. The mass loss due to strand indentation clearly has contributed to the strength loss.

**Table 2: Single and double shear test results of the Secura HGC cables and single shear test result based on BS7861 test**

*NB: hole diameter: 42 mm,*

| Test | Bonding agent (resin or Grout) | Cable UTS (MPa) | Initial pre-tension load in kN | Final ave. peak axial pretension load (kN) | Double joint peak shear load (kN) | Shear load per joint plane (kN) | Single (Guillotine) shear test (BS 7861) (kN) | DS test / BS SS Ratio |
|---|---|---|---|---|---|---|---|---|
| 1 | FB400 grout | 680 | 270 | 460 | 1600 | 800 | 679 | 1.18 |
| 2 | Carbothix | 680 | 97 | 487 | 1544 | 772 | 679 | 1.13 |

## CONCLUSION

The overall results of tested cables showed that:

- The level of shear load appears to be influenced by the cable bolt pretension load
- As expected single shear guillotine testing of the cables (based on BS7861 test procedure) yielded lower shear loads.
- The shear failure load of indented strand cable is lower than that of plain strand. This is expected because of the strength loss and mass loss of indented strands.

- No cable rotation was detected in double shear testing in either cable bolt test.

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