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PERFORMANCE OF BOLTING SYSTEMS IN TENSION AND THE INTEGRITY OF THE PROTECTIVE SLEEVE COATING IN SHEAR

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ABSTRACT: a series of laboratory tests were carried *out on sleeved bolt and domed washer plates and nuts* to determine;

- the tensile strength properties of 24 mm (200 mm core) diameter rock bolts (M24 Bolt),
- pull through testing of the bolting system consisting of bolt, domed washer plate and nut integrity,
- Integrity of the rock bolt fitted with protective plastic sleeve subjected to shearing.

All these tests were carried out on rock bolts and dome washer plates supplied by Dextra / Pretec. Pull testing was carried out in accordance with British Standard (BS 7861.1:2007). It was found that the average strength of tested bolts was 32.5 t, elongation 14.5 %. The maximum dome plate deformation load was in the order of 275 kN. No visible deterioration of the protective plastic sleeves was observed when bolts were sheared for vertical shear displacement of up to 25 mm.

INTRODUCTION

The application of tendon technology in mine openings and tunnelling has become a corner stone of ground reinforcement and stability. The technology application revolutionised the way that underground openings been constructed and led to the birth and success of the New Austrian Tunnelling Method (NATM). One benefit of the use of bolting technology has been the excavation space saving as ground reinforcement NATM with bolting/mesh and shotcrete. Less ground is excavated for bolting support for the establishment of a competent opening and has had significant economic, space and efficiency benefit in comparison other methods of steel arched concrete and masonry construction tunnelling.

Steel rock bolts or cable bolts tend to deteriorate in time with respect to corrosion when tendons are left exposed to water and moisture over prolonged period of time. Accordingly, the effectiveness and endurance of the used steel tendon system depend on the quality of encapsulation, the ground stress variations and seismicity. The use of plastic sleeves has become a focus of interest in recent years for providing protection to bolts from corrosion for long-term ground stabilisation particularly around tunnels and long term underground mining structures. Ground movement and deformation can cause elongation, bending or shearing of tendon systems, which may lead to deterioration and formation of cracks in the bolt encapsulation coating as well as the plastic sleeves, allow humidity and ground water to come

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in contact with steel rock bolts thus affecting the system long term functioning . Accordingly, this paper deals with the laboratory study of the sleeved rock bolts system supplied by Dextra / Pretec to determine:

- Tensile strength properties of 24 mm (200 mm core) diameter rock bolts (M24 Bolt),
- Integrity of the rock bolts fitted protective plastic sleeves subjected to shearing. The 3 mm thick sleeves used was 30min diameter and was not concertino in shape as was used in cable bolt coating sleeve reported by Aziz, et al., (2017)

EXPERIMENTAL PROCEEDURE

Table 1 shows the list tests carried out in accordance with the program of testing between Dextra Building Products Ltd, China / Pretec Pty Ltd and the University of Wollongong.

Table 1: List of test types

Component	Test Type	Parameters	No of tests	Test method
Bolt (1m)	Tensile	Yield Strength (YS), Ultimate Tensile Strength (UTS), Elongations at Yield Point (YP) at max. force	3	BS 7861.1:2007, Annex A
Bolt system	Pull through test	Dome washer plate deformation, pull through force and nut/ thread integrity	1	BS 7861.1:2007, Annex D
Rock bolt sleeve shear	Double shear test	Determination of the integrity of the rock bolt coated sleeve in shear	One test per vertical displacement of 15, 25 and 25 mm	UOW method of double shearing

Tensile failure testing of rock bolts

The tensile strength test involved subjecting the bolt to tension until failure, to determine the Ultimate Tensile Strength (UTS), elongation at both the yield point and at failure. Three 1.0 m bolts, supplied by Dextra were tested for ultimate failure. All three 1.0 m long bolts had the threaded ends cut out, leaving the middle 600 mm central section to be tested for tensile failure. About 350 mm lengths of the ribbed bolt sections were installed between the two large grip jaws of the 50 t Instron Universal Testing Machine (IUTM) and individually tested to failure. Figure 1 shows a general view of the tested sample and Figure 2 shows the load displacement graphs of all three tested bolts. The recorded yield load, peak failure load and displacement gare listed in Table 2. Typically, all bolts failed in tension at the near mid-section, characterised with early necking of the bolt along the strained length. The tensile failure surfaces of snapped bolt sections were characteristically of cone and cup shapes formation as shown in Figure 3.

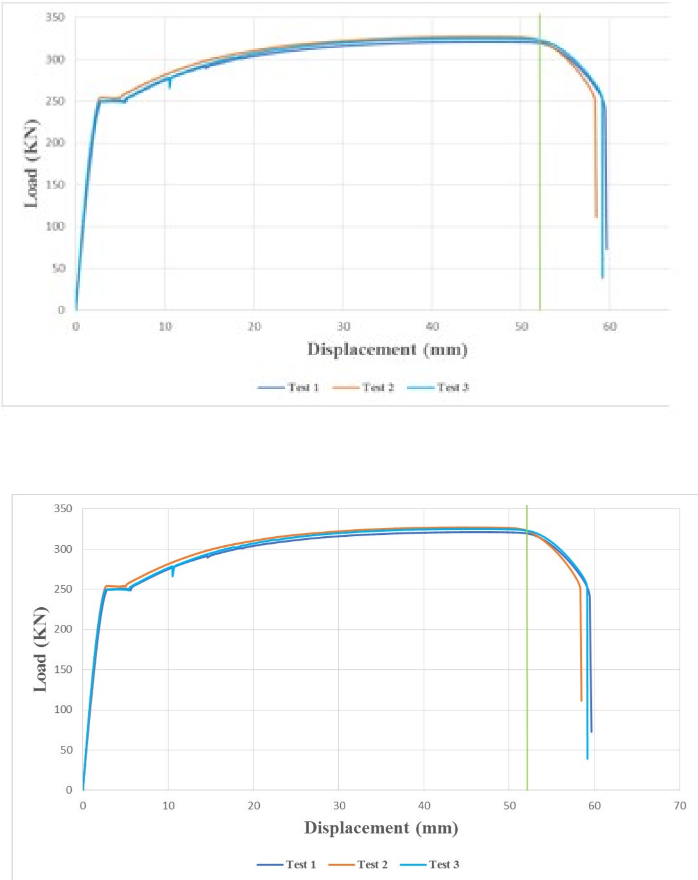

Figure 1: 50 t Instron Universal testing machine

Figure 2: Load - displacement profiles of three bolts tested at a loading rate of 1 mm/min.

Plate deformation tests

One dome plate fitted to sleeved bolt was tested for a plate deformation study. A loading frame was used for the pull testing. Figure 4 shows the assembled dome plate at the end of the sleeve bolt mounted on the test loading frame. Tests were carried out in accordance with the British standard (BS 7861-1:2007 /Appendix D). Additional photographs of the testing are shown in Figure 5 with the dome plate hole being enlarged from 55 mm to 63 mm through pulling, which enabled the bolt spherical grout injection head to pass through the enlarged hole.

Figure 6 shows the results of the dome plate deformation pull testing. The graph shows various stages of dome plate deformation and the bolt spherical grout injection head pulling through the loading frame hole. The following loads were obtained during the processing of pull testing;

1. The maximum peak load, achieved prior to the commencement of the plate deformation process was 274.73 kN with system elongation / deformation of 24 mm,
2. The second peak load depicting the start of the sudden incremental slipping of the bolt's spherical grout injection head through the gradually enlarged hole of the flattened dome-plate,
3. The third peak load in which the second sudden incremental drop of the spherical grout injection head begin to pass through the dome plate hole and gradually enlarging the dome plate hole (Figure 5).

4. Final spherical head passing fully through the enlarged dome head hole of diameter of 63 mm with a pulling force of 53 kN. This stage occurred after stage 3 pull out was stopped as shown in Figure 5.

Table 2: test details of three M24 bolts tested to failure. In (A) the individual ultimate tensile failure load and elongation, yield load and their respective elongations/displacements are shown. In (B) the average values of UTS, yield point, displacements and percentage elongation are given.

(A) Bolt sections tensile strength test results – DEXTRA Bolts							
Test No.	**Date**	**Tested bolt length (mm)**	**UTS (kN)**	**Max elongation (mm)**	**% elongation**	**YP (kN)**	**TP Disp. (mm)**
Test 1	09/05/2019	362	321.41	51.79	14.3	250	2.9
Test 2	09/05/2019	350	327.23	51.76	14.7	253	2.7
Test 3	10/05/2019	354	325.55	52.10	14.6	247	2.7

(B) Results Summary	
Average UTS (kN)	324.73
Average of max elongation (mm)	51.8
Average elongation (%)	14.5
Average yield point (kN)	250
Average elongation at YP	2.76

Figure 3: Pull tested rock bolts to failure, the failure points were at /near the middle of each test sample. Note the cone and cup failures of snapped bolt at the necking zones.

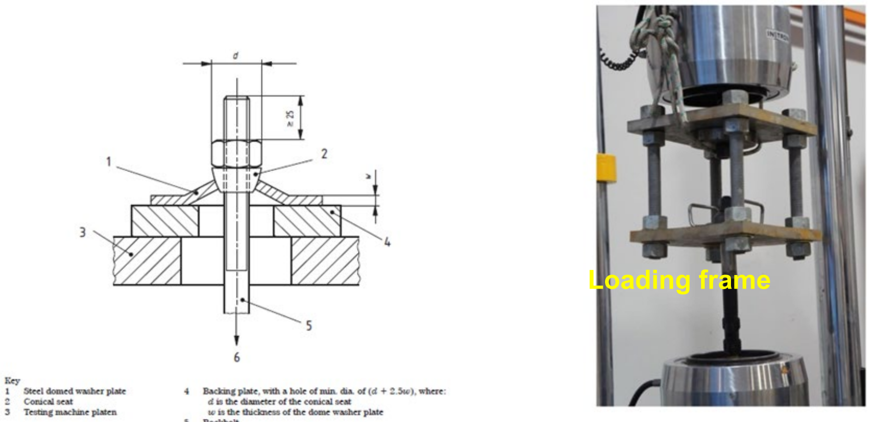

Figure 4: Test arrangement for tensile deformation testing of dome plate mounted

Figure 5: Dome washer plate and enlarged plate hole with the bolt spherical grout injection dome being pulled through the plate

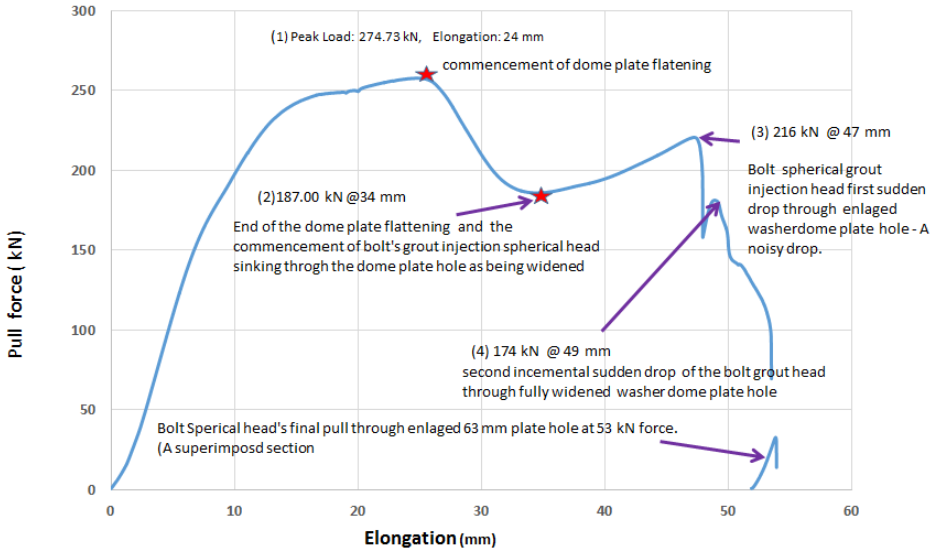

Figure 6: Pull testing of the bolt system during the various stages of pulling the bolt out of the dome washer plat

Double shear strength of sleeved bolts

The shear testing rig used was DS MK1 type rig consisting of two 150 mm side cubes and a central 300 mm rectangular central block. The rig size was adequate because of the type of test undertaken, as a limited shear displacement was needed in this study. The 300 mm long middle section of the double shear apparatus was vertically shear loaded at the rate of 1 mm/min for a specified vertical displacement. The rate of loading and displacement was monitored and simultaneously displayed visually on a PC monitor. Also monitored was the build-up of the axial loads during the shearing process. The process of preparing the sleeved bolt for double shear testing involved, grouting the sleeve on the bolt, preparation of the concrete blocks and encapsulation of the bolts in the concrete.

Grouting of the sleeve on each bolt: Prior to double shear testing the plastic protective sleeve was secured over the bolt by internal grouting. The 2 mm thick sleeve is around 33 mm in diameter with bulges, which makes the overall diameter in the order of 41mm. Figure 7 shows the methodology of the internal grouting of the sleeve on each bolt. Once held vertically the grout was poured through the hole in the spherical head of the bolt down the column annulus space between the bolt and sleeve. The grouted sleeve was left to harden for 24 hours prior to assembling the system in the double shear rig.

Concrete blocks preparation: The strength of the concrete used in the double shear testing of the sleeved bolts was 20 MPa, in order to simulate shearing in relatively soft rock formation. The sleeved bolt was to be encapsulated in 45 mm diameter hole cast in the double shear box. Concrete blocks were cast in marine plywood moulds of the same dimension as the actual steel double shear box confinements. A 30 mm diameter steel conduit rod wrapped with 8 mm diameter PVC plastic tube was used to create 45 mm hole along the concrete blocks central axis. The constituents of the concrete solid ingredient mix proportion consisted of cement /sand/gravel with the ratio of 1:1.5:3 through the pre-cut holes in the centres of the blocks. Gravel of average of 5 mm was sieved to control its size. Figure 8 shows three vertical holes cast in concrete blocks to permit charging grout through and encapsulation of the sleeve bolts in the concrete block. A 20 mm diameter PVC pipes were used to create three holes along the axial length, with one hole being made per block. Three double shear samples were cast at the same time. Once the concrete was poured into assembled moulds and let to semi harden for a period of six hours, the conduits were removed from the set concrete blocks, then followed by the removal of 8 mm PVC tubes. Figure 9 shows a typical view of the PVC tube wrapped steel conduit for creating a 45 mm hole in the concrete blocks. After 24 hours of the initial casting the concrete blocks were removed from the moulds and placed in a water bath for a period of 28 days to cure. The rock bolts were then installed in the cured blocks and each pretensioned to 50 KN force and grouted. Figure 10 shows the fully assembled DS MK-I rig being tested for shear.

Figure 7: Sleeve grouting on to bolts

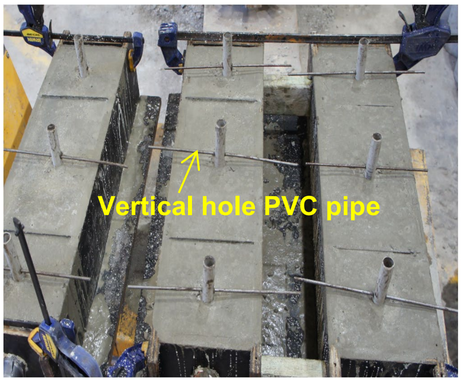

Figure 8: Vertical holes connecting with the sleeved encapsulation hold for sleeved bolt encapsulation

Figure 9: Rifling of central hole for bolt encapsulation

Figure 10: Fully assembled DS MK-I rig with a pretensioned body

TEST RESULTS AND DISCUSSION

Three assembled bolts were tested for vertical shear displacements of 15, 20 and 25 mm. The rate of shearing load was maintained constant at 1 mm/min. Figure 11 shows the profiles of the shearing for three vertical shear displacement combined into one shear load – displacement graphs. Table 3 shows the details of the three tests with maximum loads.

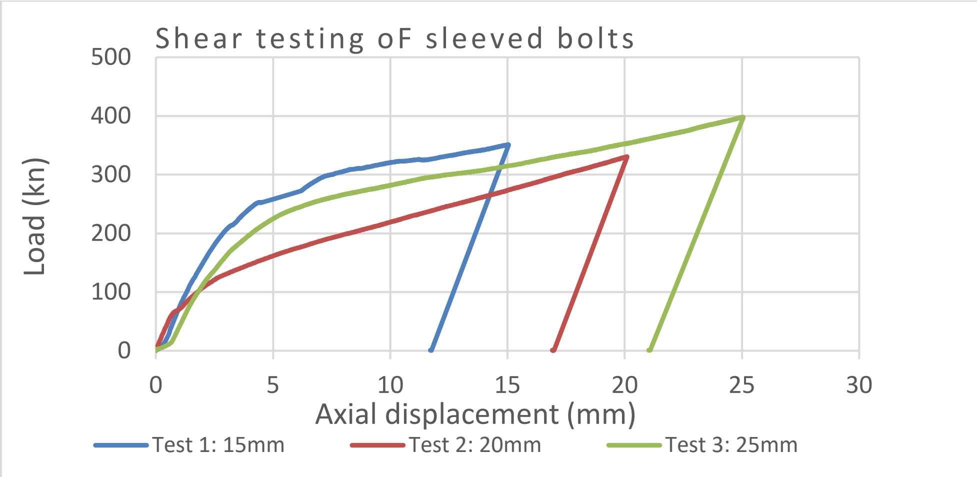

Figure 11: Profiles of the shearing for three vertical shear displacement combined into one shear load – displacement graphs

Figure 12 shows the photos of the tested blocks and exposed grouted bolt post testing. Figure 13 shows the views of the three post-test sleeves. No sleeve was torn in any of the three shear-tested bolts, however.

Table 3: Details of the three tests with maximum loads

Test Name:	Shear Test	
Test Date:	3/07/2019	
Test properties:		
sample size	MK1 (300*1050*300)	
sample strength	20 MPa	
borehole dia	45 mm	
grout type:	Crosbe (W/C 0.32%)	
Loading Machine	Instron	
Loading rate	1 mm/min	
Test results:	**Max vert displ (mm)**	**Max load (kN)**
test 1	15	351
test 2	20	331
test 3	25	398

Figure 12: photos of double shear tested block and exposed grouted bolt post testing

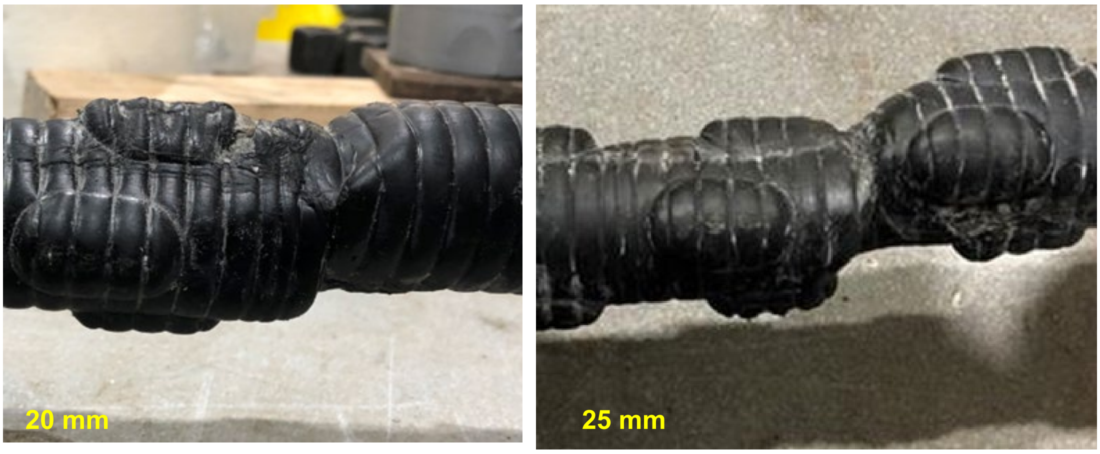

Figure 13: Typical deformation of the bolt sleeve at shear displacement of 20mm and 25 mm

CONCLUSIONS

The following conclusions are drawn from the study:

1) *Bolt strength:* The average UCS of the three tested bolts was 324.73 kN, *the average maximum elongation was 51.8* mm and average yield point was 250 kN
2) *Bolt plate and system deformation:* The maximum peak load achieved prior to the commencement of plate deformation process was 274.73 kN, at system elongation/ deformation of 24 mm. The spherical head passed fully through the enlarged dome head hole of diameter of 63 mm with a pulling force of 53 kN.
3) *Double shear strength of the sleeved bolts:* No visible deterioration of the plastic sleeves was observed when bolts were sheared for vertical shear displacement of 15, 20 and 25 mm respectively.

REFERENCE

Naj Aziz, Ali Mirzaghorbanali and Matthew Holden, 2017. The extent of shearing and the integrity of protective sleeve coating of cable bolts, Coal Operators Conference, PP 239-245.

Brtish Standards BS 7861-1, 2007. Strata reinforcement support system components used in coal mines. Part 1, specifications for rock bolting.