Dynamic, Static & Shear Testing of Normet's Urea Silicate Injection Resin and Self-Drilling Dynamic Bolt

2023 Mining Health & Safety Conference

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Normet Canada

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– SAFETY MESSAGE

Enhanced Support

It has been well documented that dynamic support systems enhance safety preventing serious injury and fatalities.

For the supplier, every effort must be taken to ensure quality control and ready stock of all bolt types required by customers. Relationships need to be built based on communication and mutual trust.

With 3 decades as customer and now 6 years as supplier, I am in the unique position of having seen it from both sides. Work as a team to meet your common goals, particularly continuity of quality product to your minesite. Be honest and open, work together.

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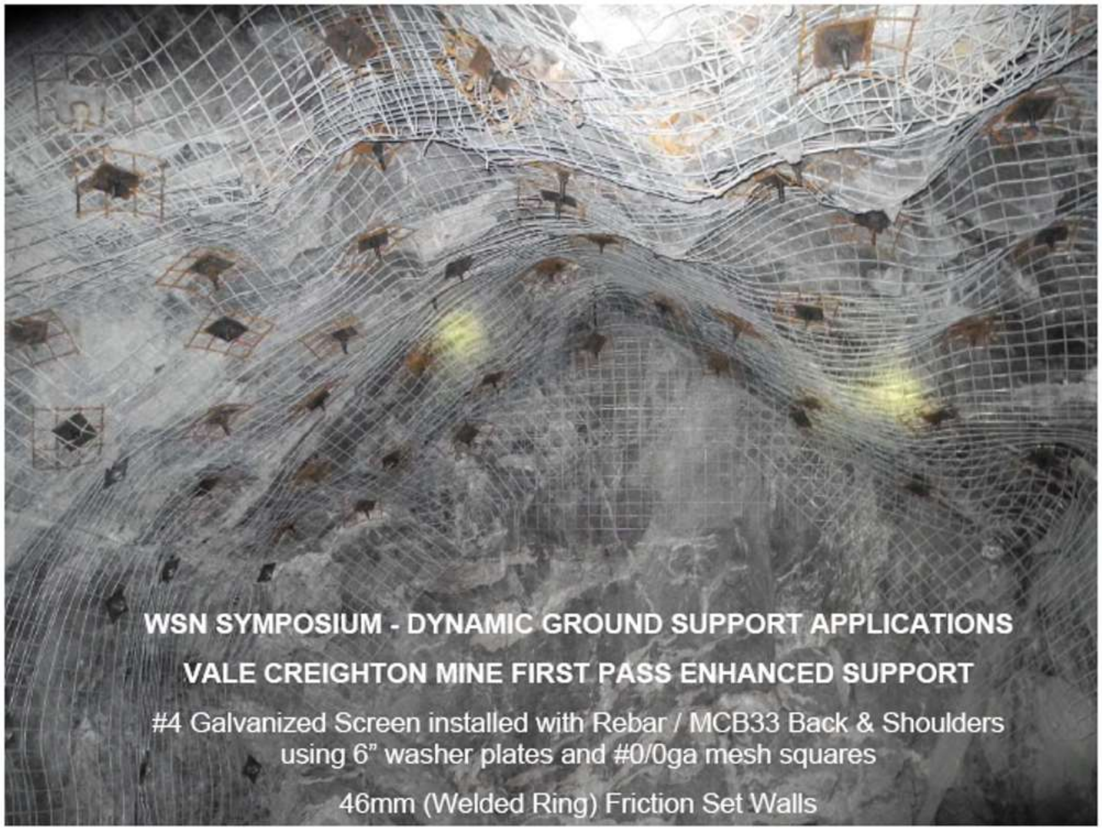
– Workplace Safety North 2014

Changes to Enhanced Ground Support Systems at a Glance

- Face bolting standards first introduced at Creighton are now widespread in the mining industry.
- The dynamic/static fully grouted combination support system using MCB-33 and rebar has now been fully replaced by D Bolt and similar designs.
- Advances in remote bolting technology remove Workers further back from unsupported ground for enhanced safety. While installation of cartridge resin can be successful in good ground conditions, rock fragments within the borehole (typically removed by an operator in semi-automated installations) tend to be problematic.



Why Dynamic Bolts: Challenging Ground Conditions

Rock Bulking / Squeezing Ground Conditions

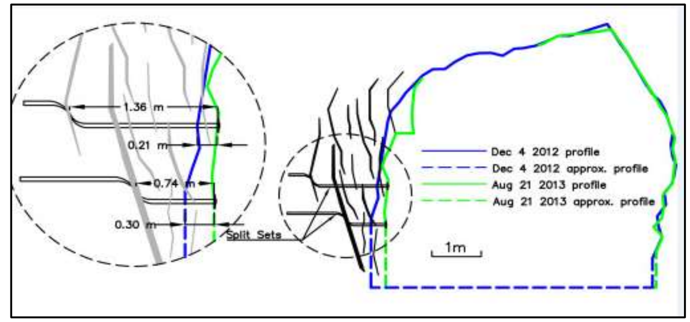
Rockburst/ Effective Opening Span

Why Dynamic?

– Why Fully-Grouted?

Ground Support System Selection?

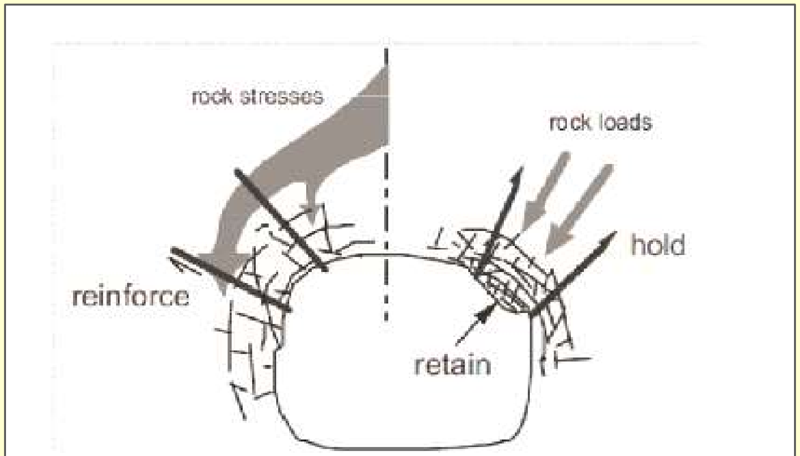
Consider fracturing following development blast and future bulking expectations based on stress redistribution as the mining front advances.



PROFILE: INTERNATIONAL JOURNAL OF ROCK MECHANICS (GROCCIA, CAI, PUNKKINEN)

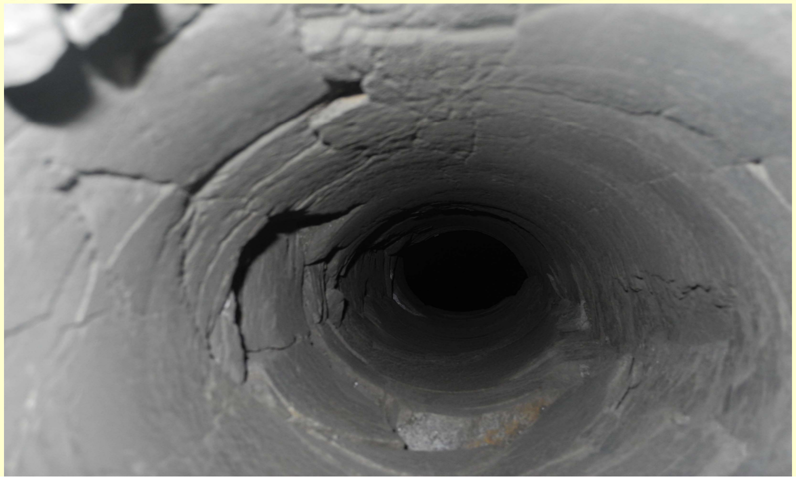
Introduction

- With many mines approaching greater depths resulting in increases in stress or adverse changes in geological conditions, implementation of dynamic support systems are introduced to assure safety of operations.



Kaiser et al., 1996

- The degree of fracturing resulting in large depth of failures over time and squeezing in primary development due to high stress conditions will result in significant effort to keep the borehole open long enough to be able to install the support component, particularly in walls and shoulders.



Technology Removing Workers from Hazardous Conditions

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2023 WSN Theme: Evolution of mining safety: Past reflections and future innovations

- With a widespread adoption of urea-silicate injection resins, it is now possible to efficiently inject hollow core bolts, eliminating previous issues with remote bolting installation.
- Prior to adoption of any ground support system, extensive trials must first be performed, underground and at independent laboratories.

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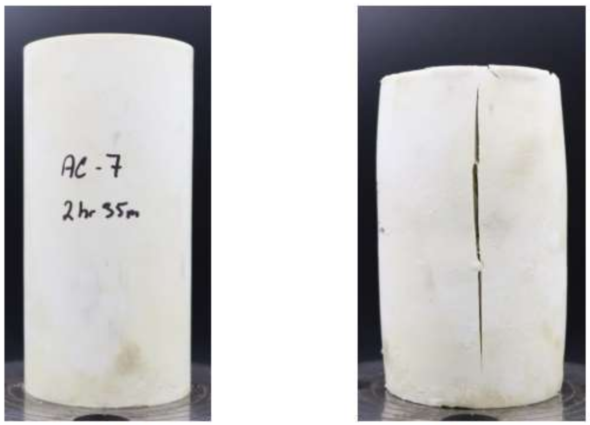
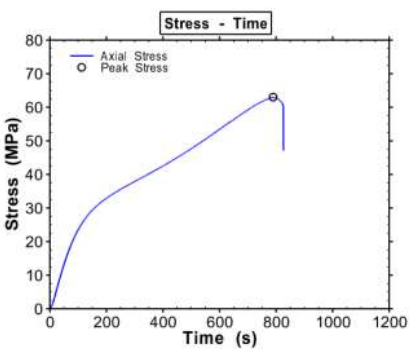
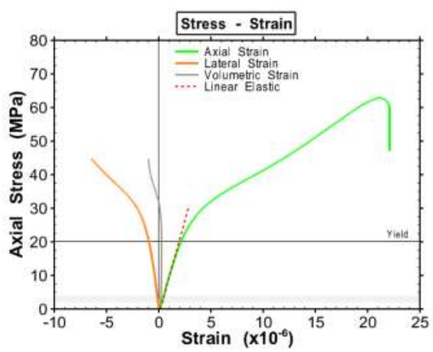
– Pumpable Resin



Pre-Test Post-Test





TECHNICAL DATA

TamPur RBG 350		
	Component A	Component B
Colour	Clear-light straw liquid	Brown liquid
Density at 20°C	1.30 - 1.57 g/cm³	1.15 - 1.35 g/cm³
Viscosity at 20°C	400±150 mPa.s	400±100 mPa.s
Reaction properties at 20°C		
Non-sagging time	Instantly	
Open time	c.a. 5 minutes	
Set time	c.a. 25 minutes	
Expansion factor	1	
Compressive strength	> 40 MPa (BS EN 196-1)	

Figures based on laboratory results

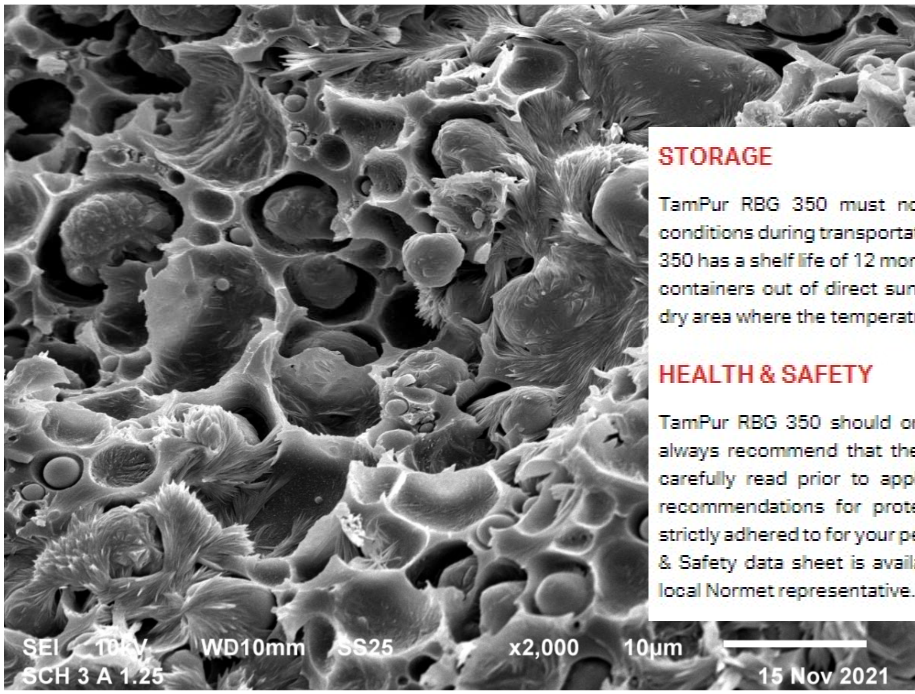
— 2000x magnification a scale (10-micron range scale shown, bottom right).

STORAGE

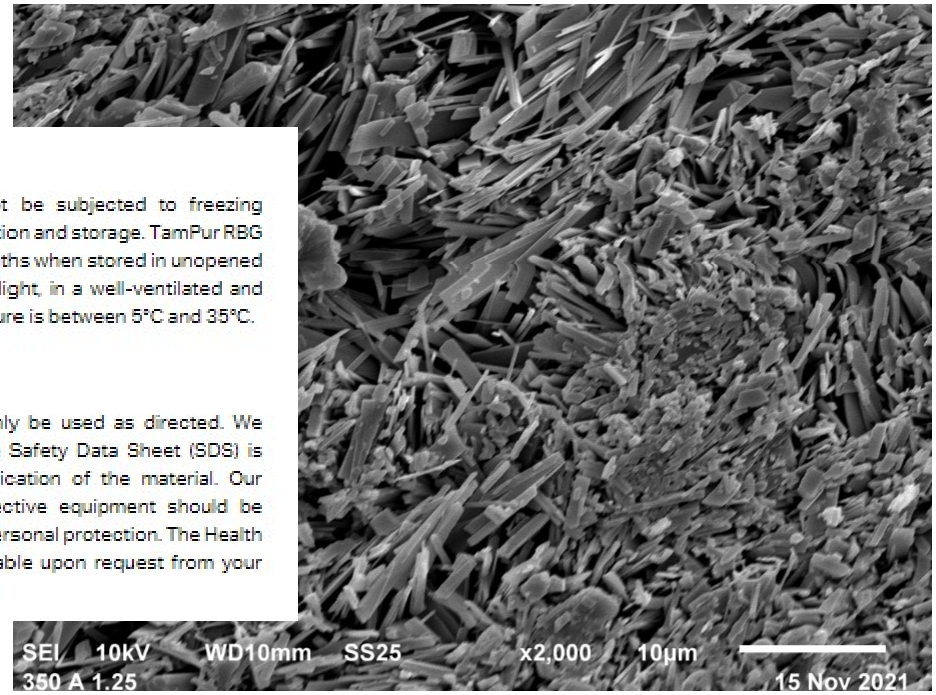
TamPur RBG 350 must not be subjected to freezing conditions during transportation and storage. TamPur RBG 350 has a shelf life of 12 months when stored in unopened containers out of direct sunlight, in a well-ventilated and dry area where the temperature is between 5°C and 35°C.

HEALTH & SAFETY

TamPur RBG 350 should only be used as directed. We always recommend that the Safety Data Sheet (SDS) is carefully read prior to application of the material. Our recommendations for protective equipment should be strictly adhered to for your personal protection. The Health & Safety data sheet is available upon request from your local Normet representative.



A good resin with even matrix of polyurethane and closed cells with silica balls.

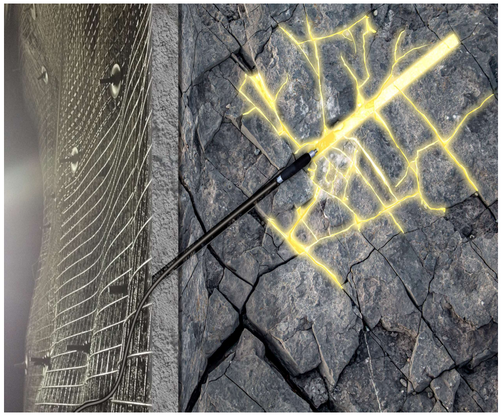


Bad resin – resulting in low strength and plasticity (toughness) with messy structure of long crystals of polyurethane resulting in brittle resin.

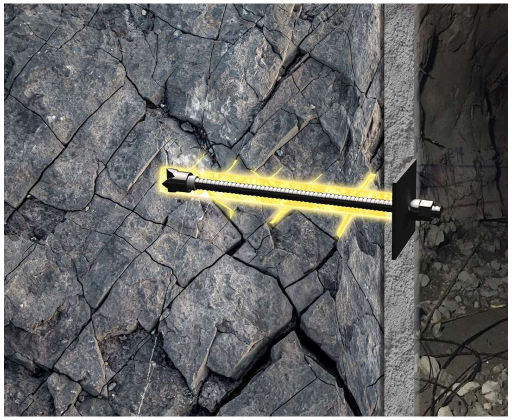
ROCK AND
GROUND SUPPORT

Urea Silicate Resins

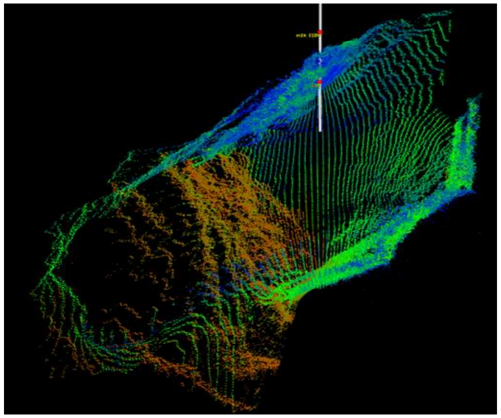
Non-Foaming



Rock Bolt Grout (RBG)



Foaming



Non-Foaming & RBG are solid resins and used fundamentally as a glue in rock formation or securing rock bolts
Foams are a high expansive system and used for filling voids

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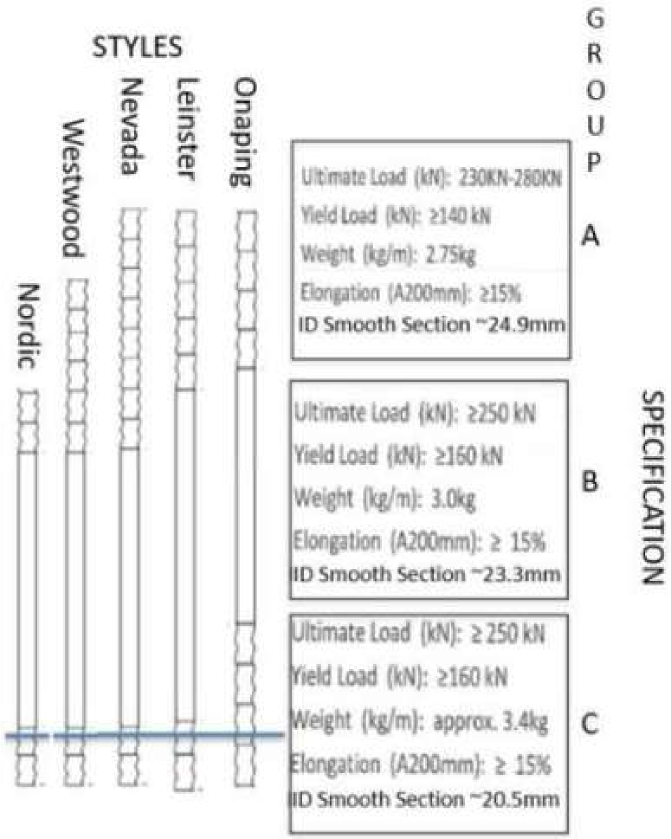
- SDDB Configuration



CURRENT CANADIAN SDDB STYLES

NEVADA Style - Group A 2.4m
250-1100-1050 (Avg. length r32-Smooth-r32)

Nordic Style - Group B 1.5m
150-1200-150

Onaping Style - Group C 2.4m
600-1200-600

In Production:

Westwood Style - Group B 2.1m
250-1250-600

New:

NEVADA-Onaping Group B 2.4m
250-1550-600

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– Group A-B-C Manufacturer Specifications

TECHNICAL DATA Group A

Technical Data	
Ultimate Load (kN) theoretical / typical	> 230 kN / ≥ 245 kN
Yield Load (kN) theoretical / typical	> 140 kN / ≥ 160 kN
Weight (kg/m)	÷ 2.75 kg
Elongation (A 200 mm)	≥ 15%

TECHNICAL DATA Group B

Technical Data	
Ultimate Load (kN) theoretical / typical	> 250 kN / ≥ 270 kN
Yield Load (kN) theoretical / typical	> 160 kN / ≥ 180 kN
Weight (kg/m)	÷ 3.0 kg
Elongation (A 200 mm)	≥ 15%

TECHNICAL DATA Group C

Technical Data	
Yielding Load	Min.190 kN
Ultimate Load	Min.270 kN
Elongation (A 200 mm)	≥ 15%
Shear Strength	Min. 162 kN; typical over 200 kN
Mass per meter	3.5 kg

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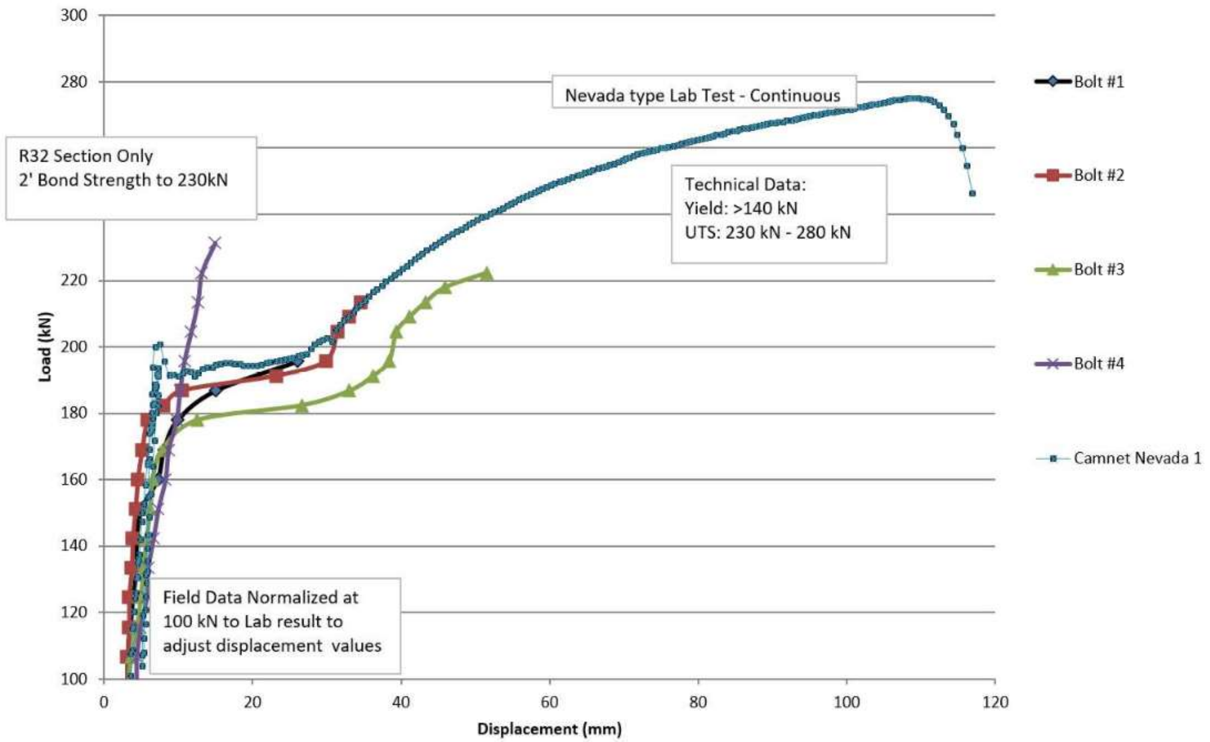
– Underground Pull Testing (Group A – Nevada)



Underground Pull Testing. Showing Canmet Lab Result

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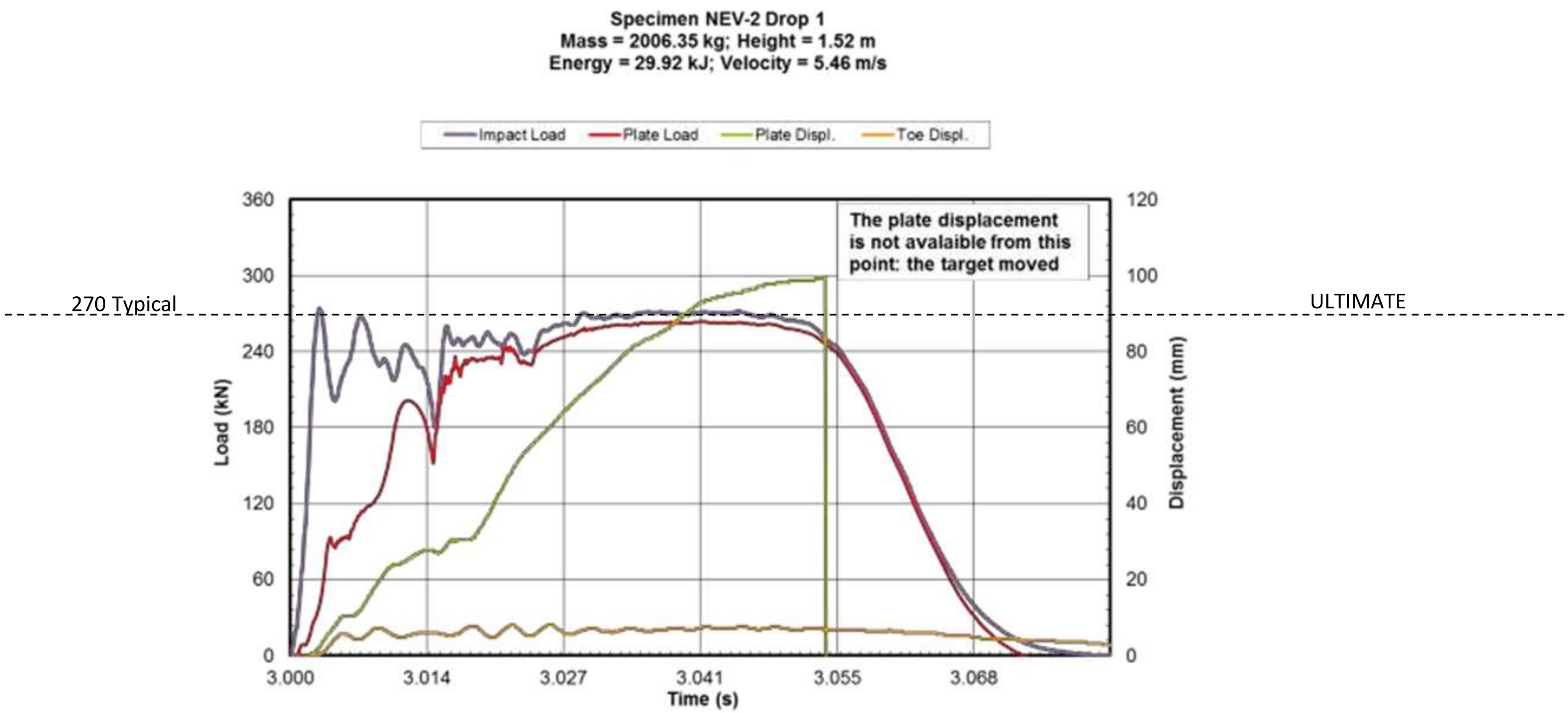
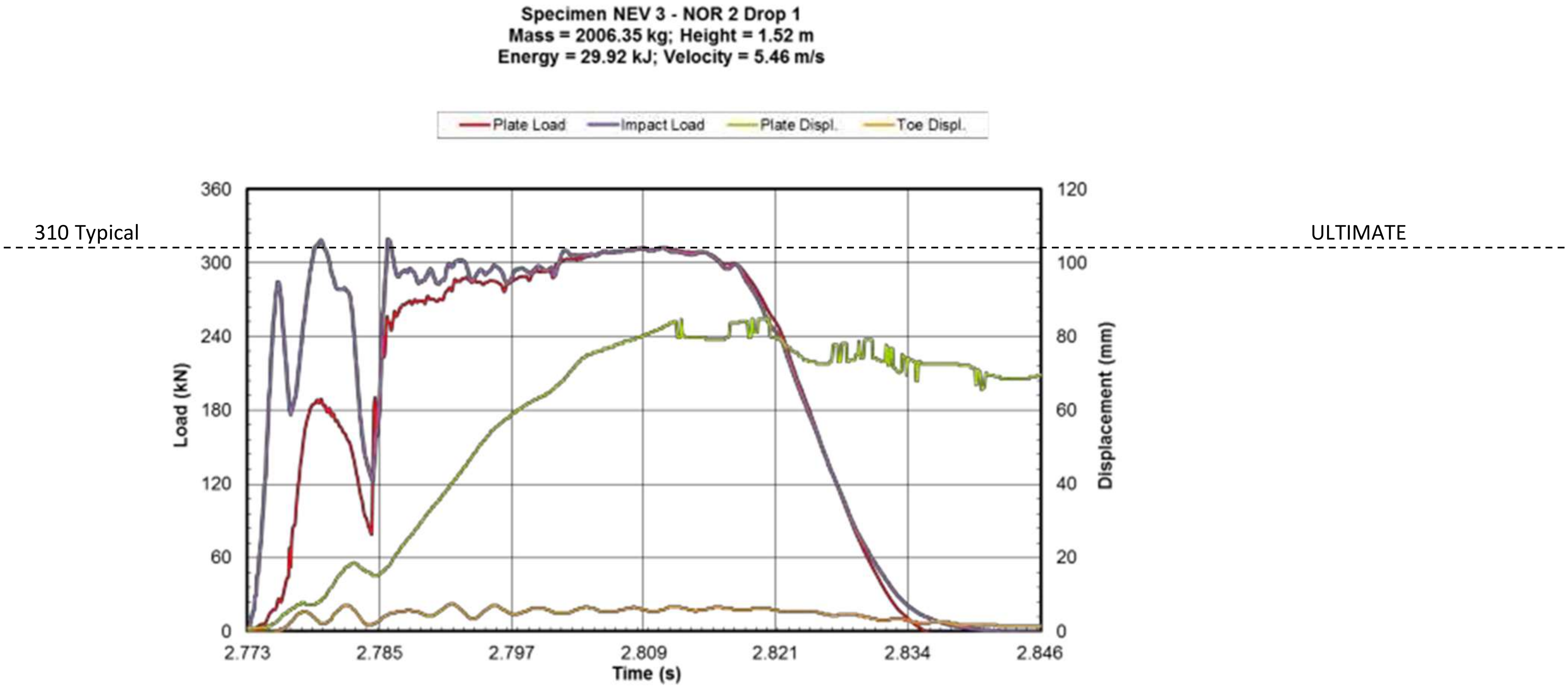
– Group A- Indirect Drop Test 1st Impact 29.92 kJ



– Group B- Indirect Drop Test 1st Impact 29.92 kJ



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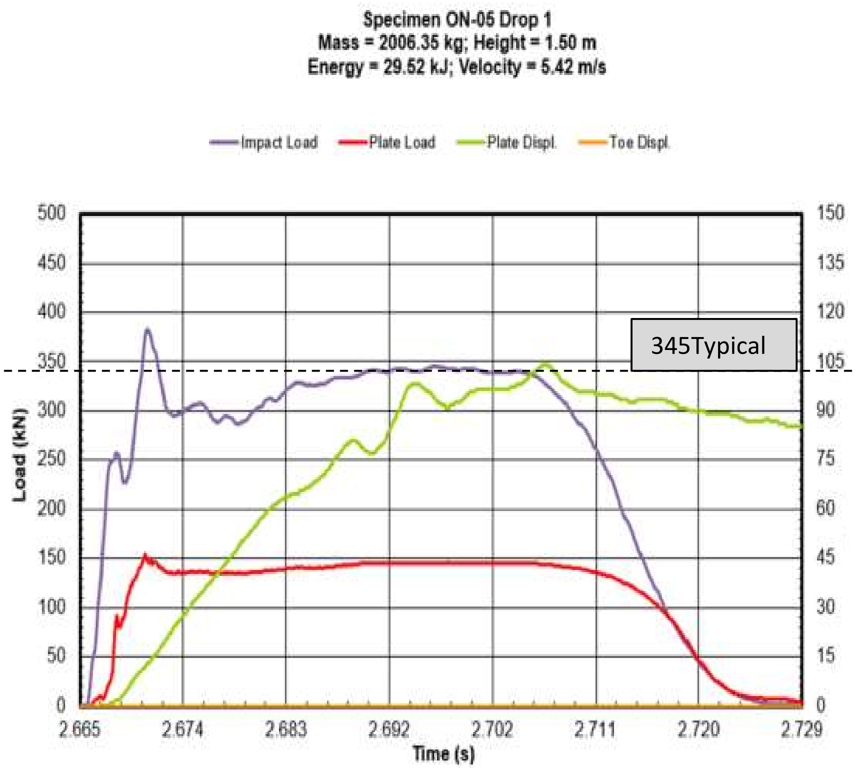
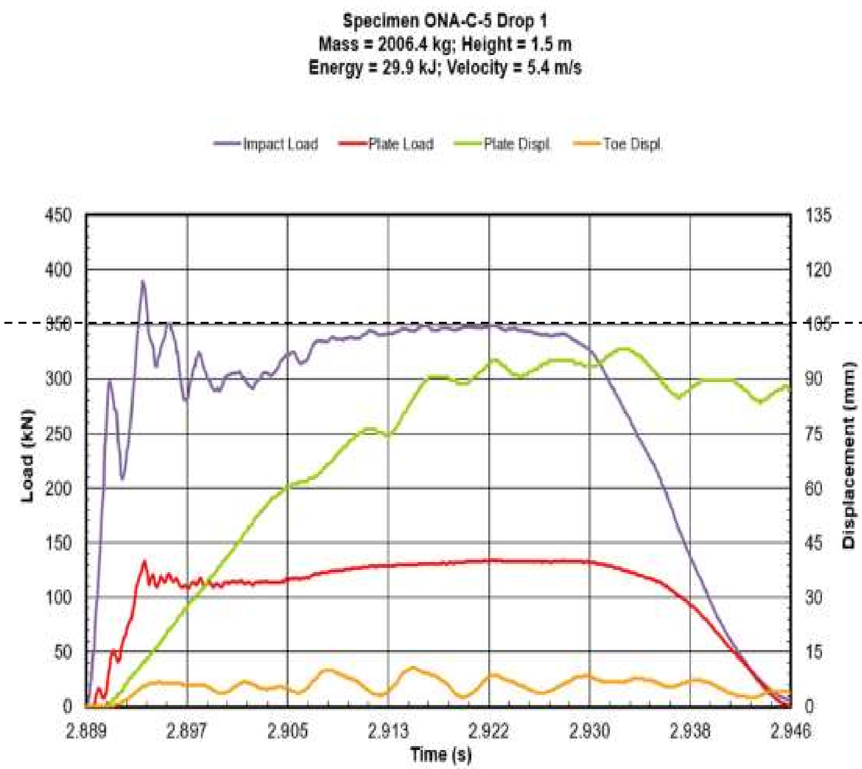
– Group C- Indirect Drop Test 1st Impact 29.92 kJ



USING NORTH AMERICAN RESIN



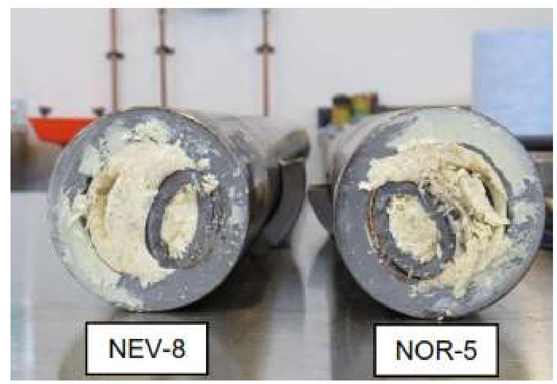
Lab Testing Group A-B (2019)

Urea-Silicate Injection Resin with SDDB – Static Shear Tests

	Sample #	Yield Load	Maximum Shear Load	Failure Load	Displacement	Type of config.
		(kN)	(kN)	(kN)	(mm)	
A	NEV-9	76.0	196.5	131.3	27.3	On thread
A	NEV-8 / D20 Plate	65.4	224.2	203.6	31.1	On bar
B	NOR-5 / D17 Plate	82.2	259.7	166.7	29.0	On bar

Break on Threaded Section

Break on Smooth Section



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Lab Testing Group C (Q4-2020)

Max. Shear Load in Pipe – 2019 Group A	**224.2 kN**
Max. Shear Load in Pipe – 2019 Group B	259.7 kN
Max. Shear Load in Pipe – 2020 Group C	286.2 Kn


ON-04: Failure profile


ON-12: Failure profile


ON-13: Failure profile

Table A.3 - Shear Test Results

Specimen ID	Bolt Type/Style	Configuration	Initial Bolt Length (mm)	Final Bolt Length (mm)	Elongation (mm)	Yield Load (kN)	Maximum Load (kN)	Failure Load (kN)	Displacement (mm)	Comments
ON-04	Onaping	Direct shear, hardened resin in core	2412	2415	3	75.7	214.6	198.2	12.4	Failed mid-bar
ON-12	Onaping	Shear on bolt grouted inside of steel tube	2408	2411	3	103.8	282.6	209.8	27	Failed mid-bar
ON-13	Onaping	Direct shear, nude bar with no resin	2410	2415	5	75.6	206.6	182.4	13.2	Failed mid-bar

Typical SDDB Shear Strength vs. Ultimate Load as Measured within Resin Grouted Tube

R32 SDDB	Max. Shear Load	Ultimate Load - Typical (Indirect Drop Tests 29.92 kJ)	Measured Shear Strength (% of Ultimate)
Pipe – 2019 Group A	224.2 kN	270 kN	83.0 %
Pipe – 2019 Group B	259.7 kN	310 kN	83.8 %
Pipe – 2020 Group C	286.2 Kn	345 kN	83.0 %

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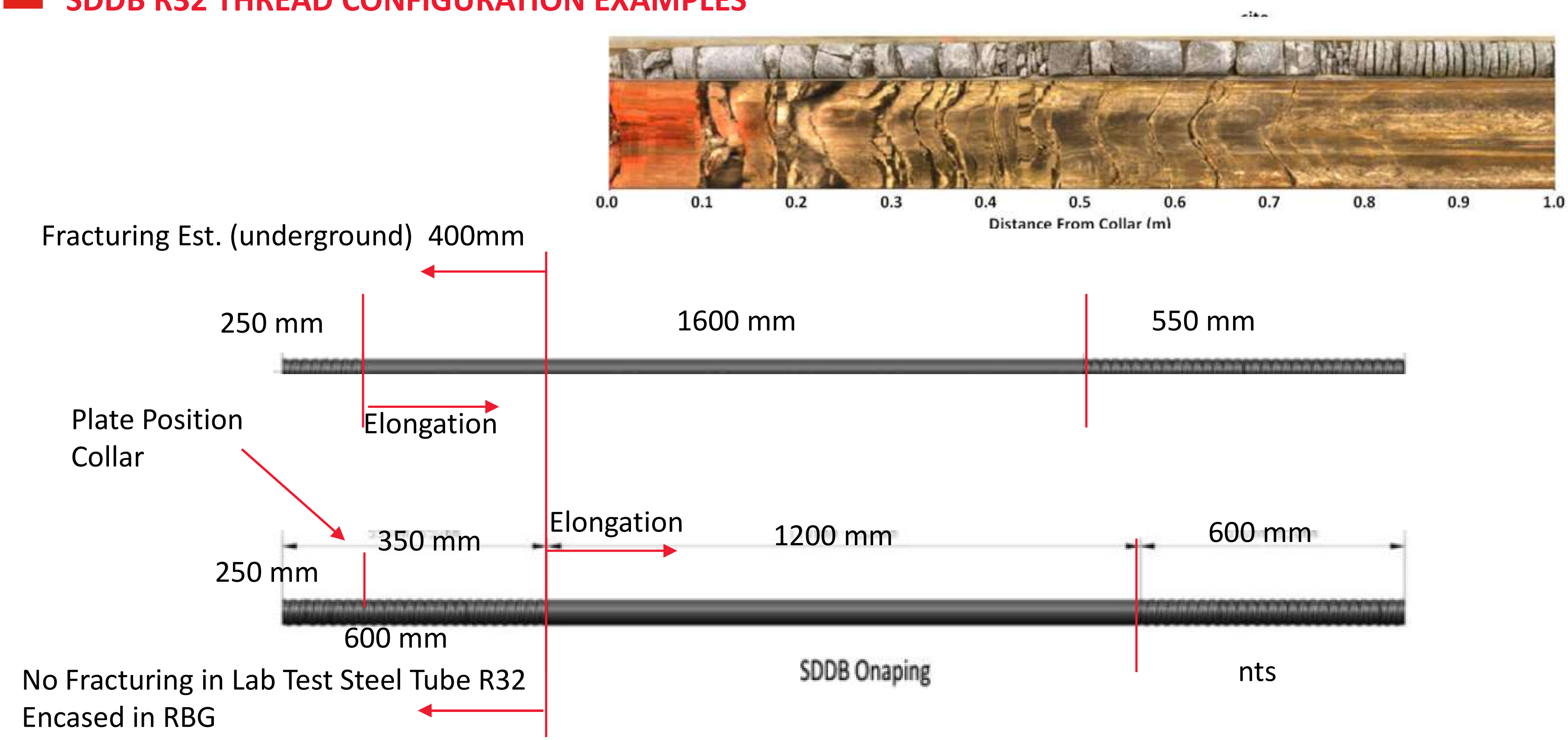
SDDB R32 THREAD CONFIGURATION EXAMPLES



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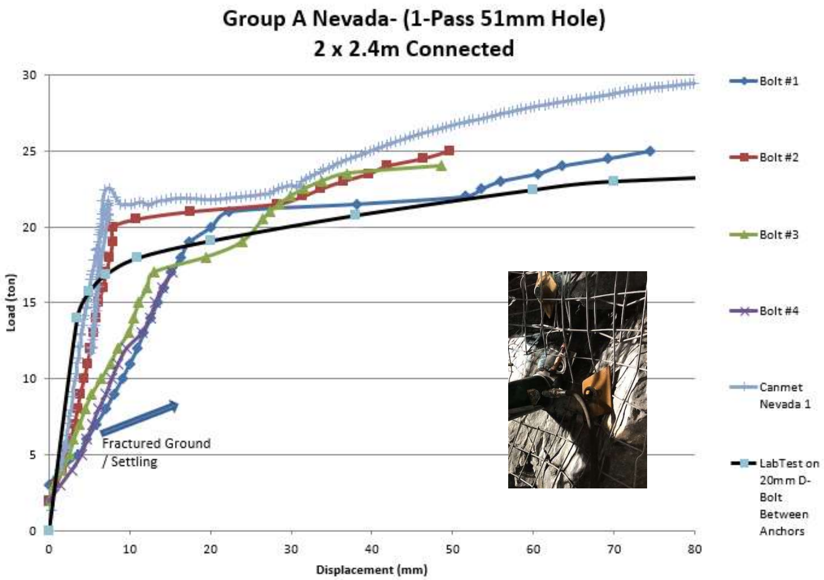
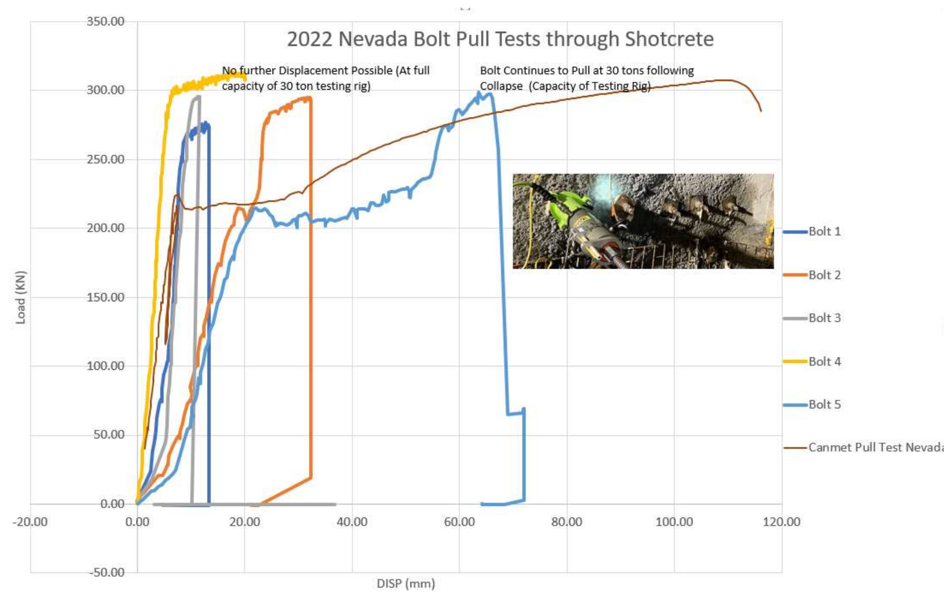
– Pull Testing (Group A)

Test 1-4 exhibit stiff behaviour (250mm R32 section locked in Shotcrete)
Test 5 reveals clear post-yield plastic behavior of the smooth bar section after yield, no bond at shotcrete



Smooth Bar at Collar

All tests in fractured rock, clear post-yield plastic behaviour



R32 Thread within Shotcrete

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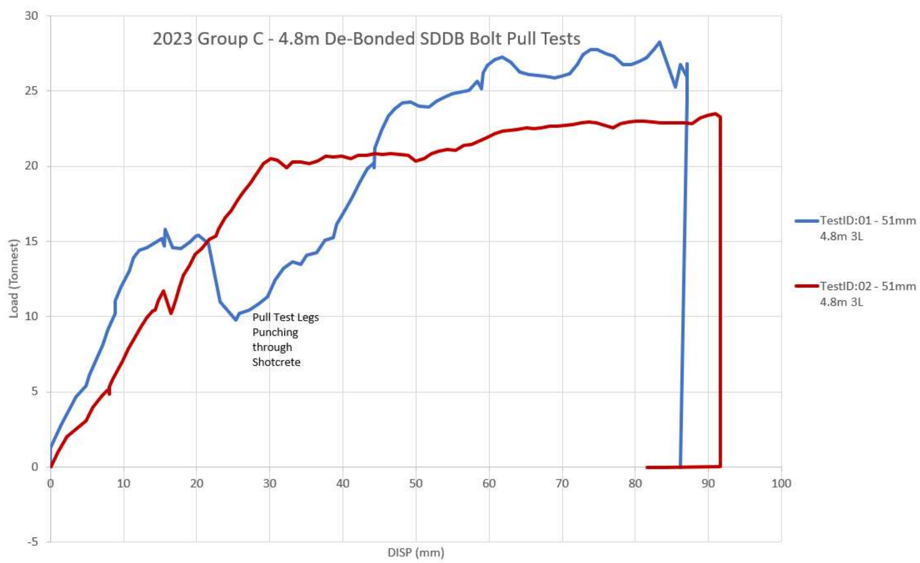
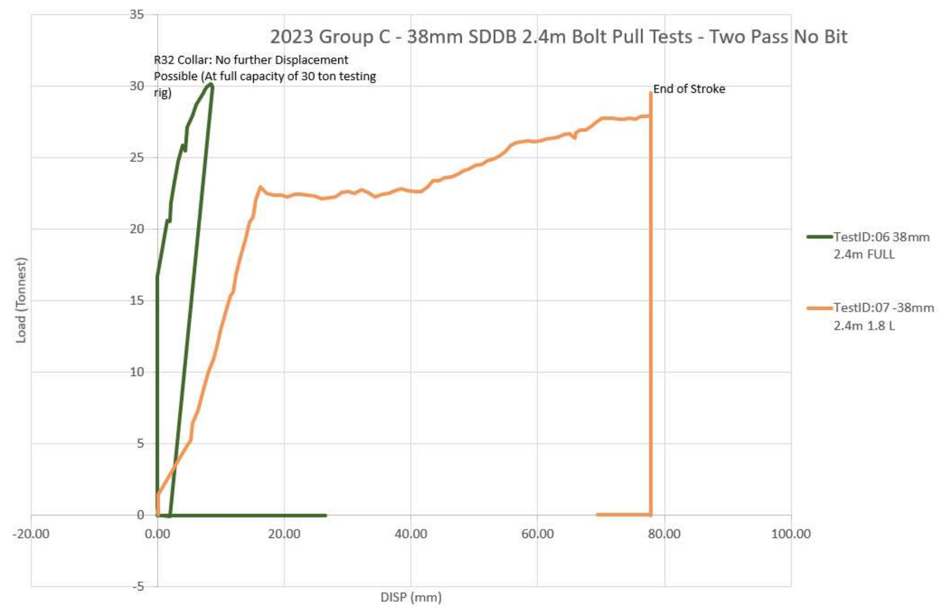
– Pull Testing (Group C)





Smooth Bar at Collar

Coupled 2.4m SDDB, 3 litres Resin (600mm R32 Toe Embedment)

2.4m SDDB R32 @ Collar & Smooth Bar (600mm Toe Embedment)

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5.0 Lab Testing (Q4-2020) Group C

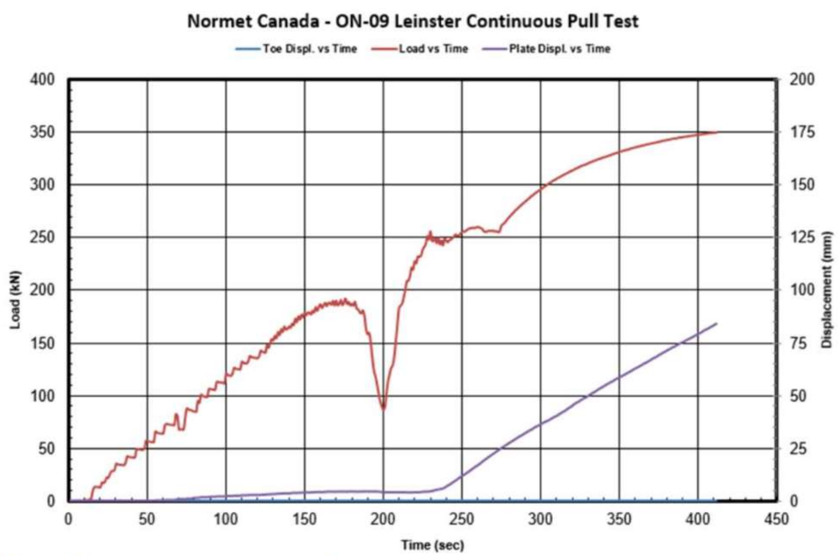

Figure 12. Leinster style continuous pull test

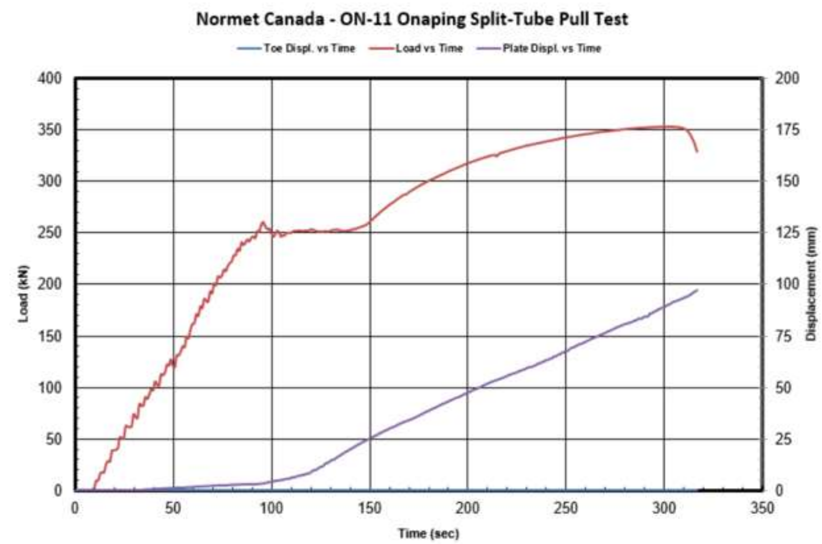

Figure 13. Onaping type split-tube pull test

5.0 Lab Testing (Q4-2020)

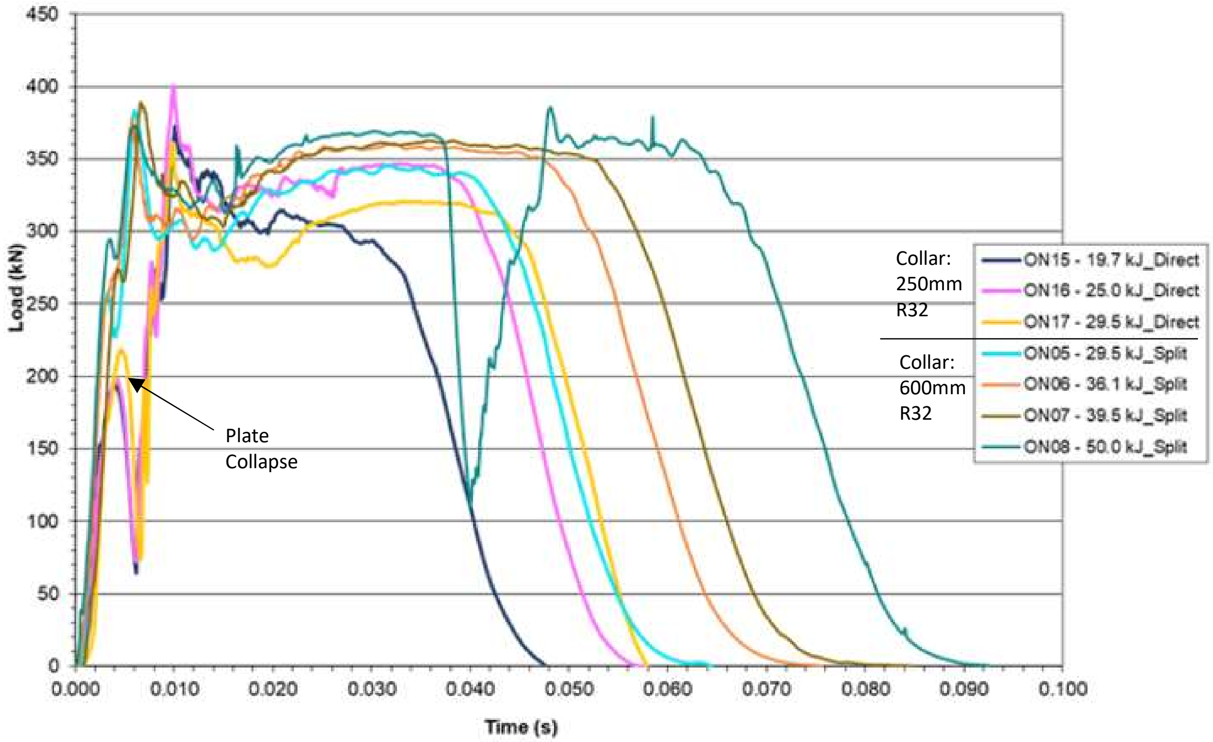

Figure 14. Load vs Time curve at drop 1 - Leinster (direct impact) and Onaping (indirect impact)

On03 19.7kJ Direct

Collar:
600mm
R32

5.0 Lab Testing (Q4-2020)

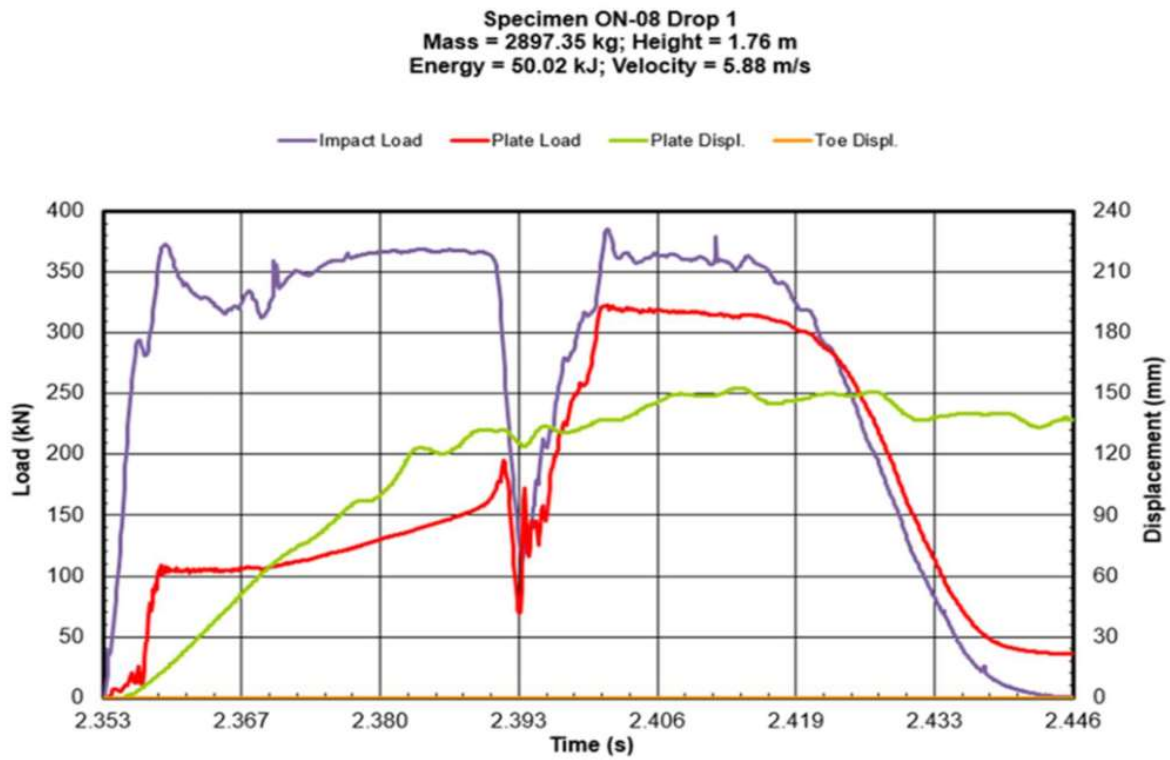

Figure 16. Onaping type indirect impact (50 kJ) drop 1 of 1 (plate collapse, no bolt failure)

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Lab Testing (Q4-2020)

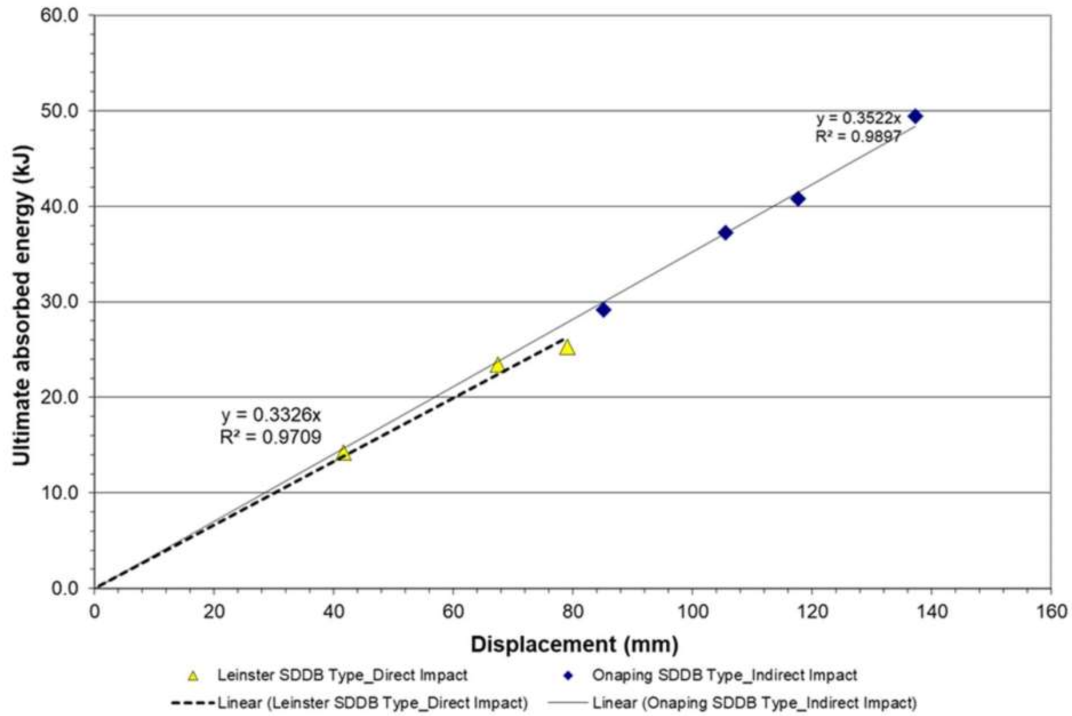
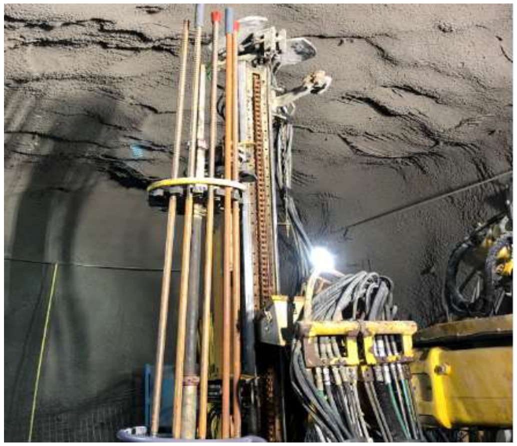


Figure 15. Ultimate Absorbed Energy vs Displacement curve at the first drop - Leinster (direct impact) and Onaping (indirect impact)

CONCLUSION

As mines progress to ever increasing depth, new challenges are encountered with serious concerns for rock excavations in highly stressed conditions. New procedures have been undertaken or are under way to remove workers from the workface, mitigating risk and exposure to hazardous conditions. Rockbolting crews are at particular risk as they are the first line of defence in the installation of the ground support systems.



An important innovation for removal of workers from danger has been the implementation of remote bolting. Equipment manufacturers have had the ability to remotely inject resin pneumatically into boreholes for several years, but it has not been recognized as a very productive method due to a variety of complications.

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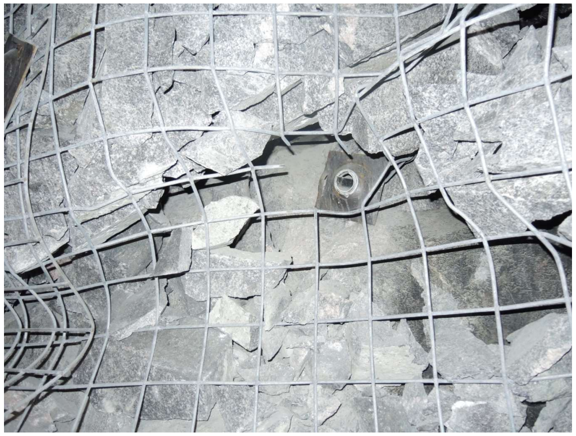
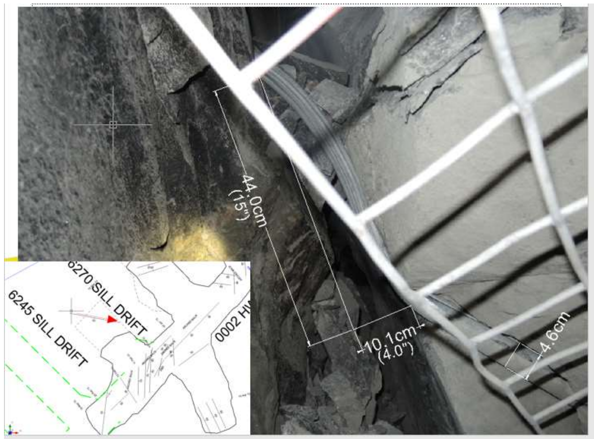
CONCLUSION

Prior to implementing any ground support component, extensive research must be carried out to prove the efficacy for use within a ground support system. Independent testing must be carried out in a laboratory environment with underground testing, procedures, bulk installation and a Management of Change (MOC) carried out at the mine as part of the Quality Control program.

Always, review should be completed by mining operation to establish best support component properties based on depth of fracturing to match surface support components. Whereas failure is likely with impact direct on the plate with a stiff collar component in a laboratory environment, the bulk of fracturing surrounding the mine opening is created with the blasted round and redistribution of stresses thereafter, prior to installation of any support components.





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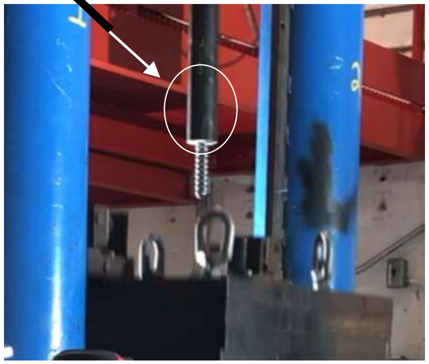
CONCLUSION

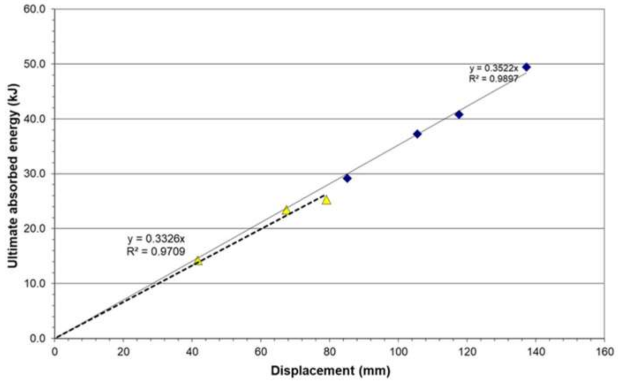
2020 lab testing confirms that in the case of direct impact at the plate, a 600mm R32 thread fails at the threads with resin encompassing R32 to collar. This does not adequately represent wall conditions underground. Fractured ground cannot hold stress as it is previously failed. It is only then subsequently bolted into place.

Four dynamic indirect impact tests on the Onaping SDDB were completed:

The cumulative strain of ON-05 (29.5kJ – 3 Impacts), ON-06 (36.1kJ – 2 Impacts), ON-07 (39.4kJ- 2 impacts) and ON-08 (50kJ – 1 Impact) were 20.4%, 18.9%, 19.0%, and 12.0% respectively.

R32 Well Incapsulated within resin





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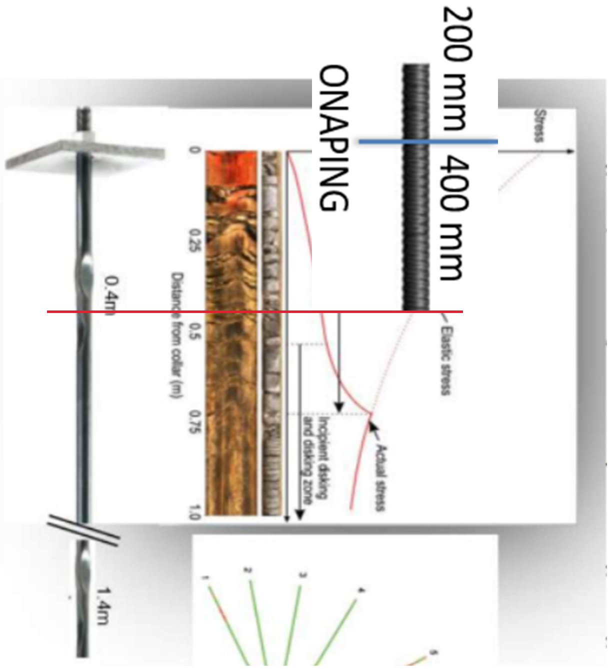
CONCLUSION

Full bond strength is achieved with 600mm R32 thread, locking in the bar at the toe.

With a nominal 350-400mm grouted within the collar of the borehole, the depth of resin is similar to that of D Bolt cartridge resin at the collar.

As a static support, high bond strength at the collar performs as an excellent holding mechanism which cannot hold stress as it is previously failed.

In high stress conditions, the load is first applied to the bolt dynamically inside the rock, subsequently loading the plate as bulking occurs within the fracture zone.



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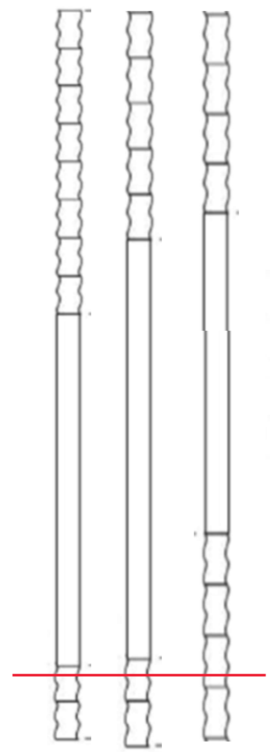
CONCLUSION

Secondary support can now be performed in-cycle with Primary installation. The smaller hole diameter of Group C bolts are an excellent choice for connection. It is now possible to connect 2-3 SDDB with the Epiroc bolter,.

Finally, for quality control purposes, it is ideal to prescribe the SDDB where possible with equal length of thread on bolt ends as it is less difficult to discern which "end is up" after the bolt has been installed.



Ultimate Load (kN): 230KN-280KN
Yield Load (kN): ≥140 kN
Weight (kg/m): 2.75kg
Elongation (A200mm): ≥15%
ID Smooth Section ~24.9mm

Ultimate Load (kN): ≥250 kN
Yield Load (kN): ≥160 kN
Weight (kg/m): 3.0kg
Elongation (A200mm): ≥ 15%
ID Smooth Section ~23.3mm

Ultimate Load (kN): ≥ 250 kN
Yield Load (kN): ≥160 kN
Weight (kg/m): approx. 3.4kg
Elongation (A200mm): ≥ 15%
ID Smooth Section ~20.5mm

THANK YOU!

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