



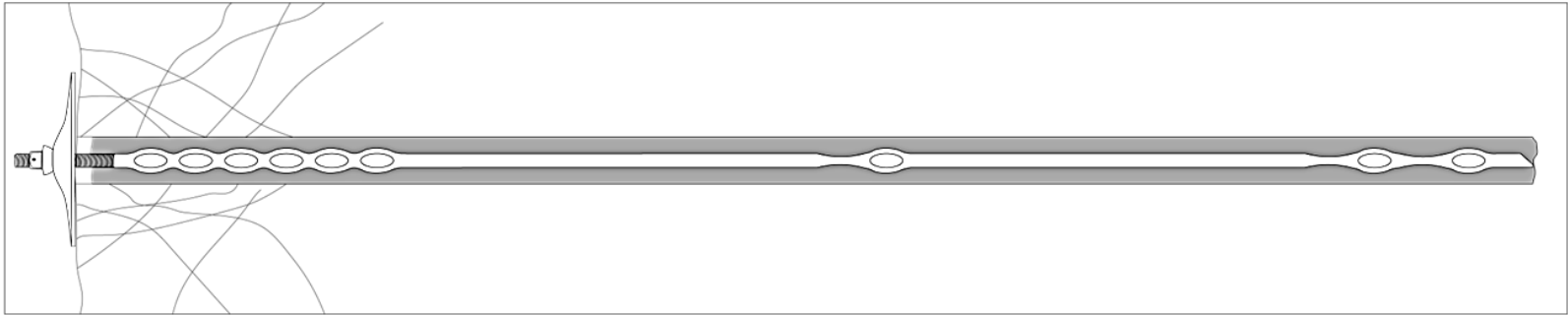
# **Static and Dynamic Behaviour of the VersaBolt™**

*Presented by*

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# General Description



- The VersaBolt™ is designed for ground support conditions that are subject to static or dynamic stresses where conventional bolting techniques are too rigid.
- The bolt is made from a smooth steel bar with either two or three anchors positioned along its length. The end anchor has 4 deformations and the collar anchor has 6 deformations.
- The specialised steel used has both high tensile strength and elongation properties.
- The bolt can be installed in a drilled hole with either resin or cementitious grouts with equally similar properties.
- Once installed, the anchors become fixed and do not move within the grout column. In the event of a rockburst or rock dilation due to squeezing ground, the smooth bar sections between the anchors will elongate.

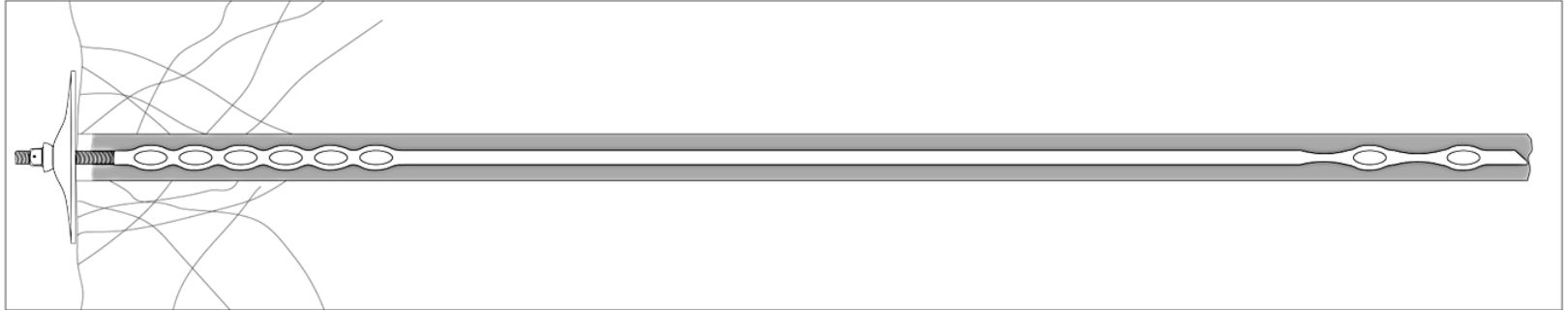
# The Design Elements

- In the first phase of the loading process, the bolt is stiff and will behave similarly to that of a resin rebar however once the yield point is exceeded, the steel plastically deforms allowing for controlled deformation of the rock mass.
- It is these unique design properties that allow the bolt to absorb the energy of either a rockburst or squeezing ground.
- The anchor at the end of the bolt is the most important one. The VersaBolt™ is considered a point anchored bolt therefore the end anchor must support the full tensile capacity of the steel without slipping under all conditions. For this reason, we have added extra deformation in this anchor zone to ensure that even in circumstances where the borehole is enlarged or the bar is installed under less than ideal conditions, the end anchor will still have sufficient capacity to meet or exceed the full tensile strength of the steel. The three anchors are designed to support the full capacity of the steel.

# The Design Elements

- The bolt is available in two different bolt diameters, 20mm and 22mm and the number and location of the anchors can be configured depending on the specific needs of the client. The standard bar configuration has three anchors positioned along the anchor bolt and each serves a distinct purpose. The end anchor has four deformations and as described above is fixed. The anchor at the threads is designed to create a rigid zone so that the static or dynamic stress exerted on this anchor zone is transferred via steel stretch to the middle anchor. As a general rule, ground conditions at the collar can be highly fractured and or the drill hole enlarged. For this reason, we have designed the thread anchor with a total of 6 deformations to better ensure that under adverse conditions, the bar in this zone is well anchored. This also eliminates or greatly reduces loading on the threads and plate when the rock dilates

# Second Design



- The second configuration comprises of only two anchor points, one at the end and one at the collar.
- When the bar is completely encapsulation up to the collar with resin or cement, the load is transferred to the anchor element at the end of the bolt.
- The longer smooth section of the bolt will allow for more plastic deformation, which further reduces the rigidity of the support.
- This configuration is particularly useful when the mine is experiencing high rock dilation but it can be an interesting consideration under certain dynamic loading conditions as well.

# Technical Specifications

Smooth Bar Steel Specifications	20 mm VersaBolt		22 mm VersaBolt	
	Minimum	Typical	Minimum	Typical *
<b>Yield Strength</b>	<i>151 kN - 16.9 tons</i>	<i>165 kN - 18 tons</i>	174 kN- 19.6 tons	193 kN - 21.7 tons
<b>Ultimate Tensile Strength</b>	<i>201 KN - 20.7 tons</i>	<i>237 kN - 26.6 tons</i>	233 kN - 26 tons	259 kN - 29 tons
<b>Elongation</b>	17%	24% **	17%	24%**

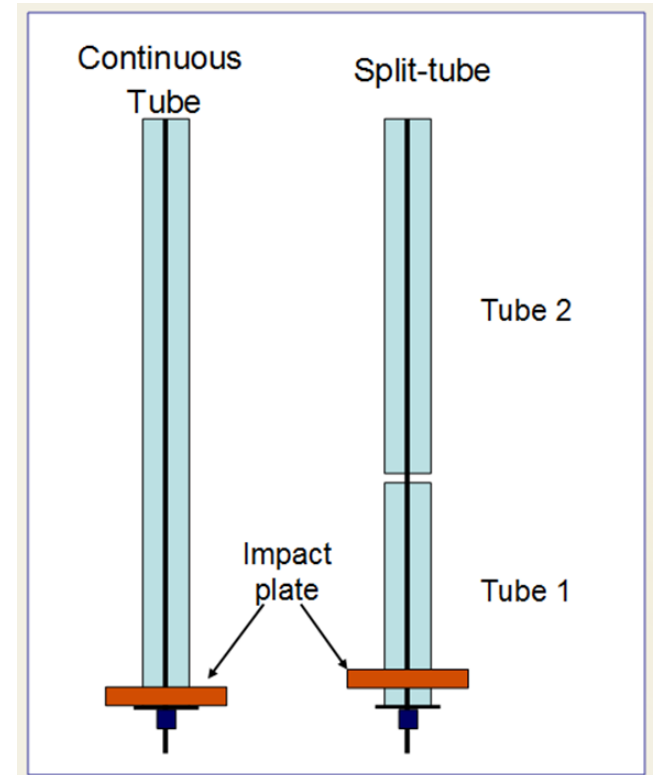
Threaded Steel Section				
	Minimum	Typical	Minimum	Typical *
<b>Yield Strength</b>	<i>133 kN - 13.4 tons</i>	<i>160 kN - 18.5 tons</i>	154 kN - 17.3 tons	193 kN - 21.7 tons
<b>Ultimate Tensile Strength</b>	<i>185 KN - 21 tons</i>	<i>213 kN - 24 tons</i>	214 kN - 24 tons	259 kN - 29.1 tons

\* As tested by Canmet

\*\* Based On Mill Test Certificate

# Canmet Dynamic and Static Testing Methods

- There is two testing methods, continuous or split tube
- Using the continuous method the load is dropped onto threads whereas in the split tube method, the steel tube is split between two anchors and the smooth bar section absorbs the load
- The split tube method is the generally accepted testing method for this style of bolt



# Dynamic Capacity as Tested by Canmet

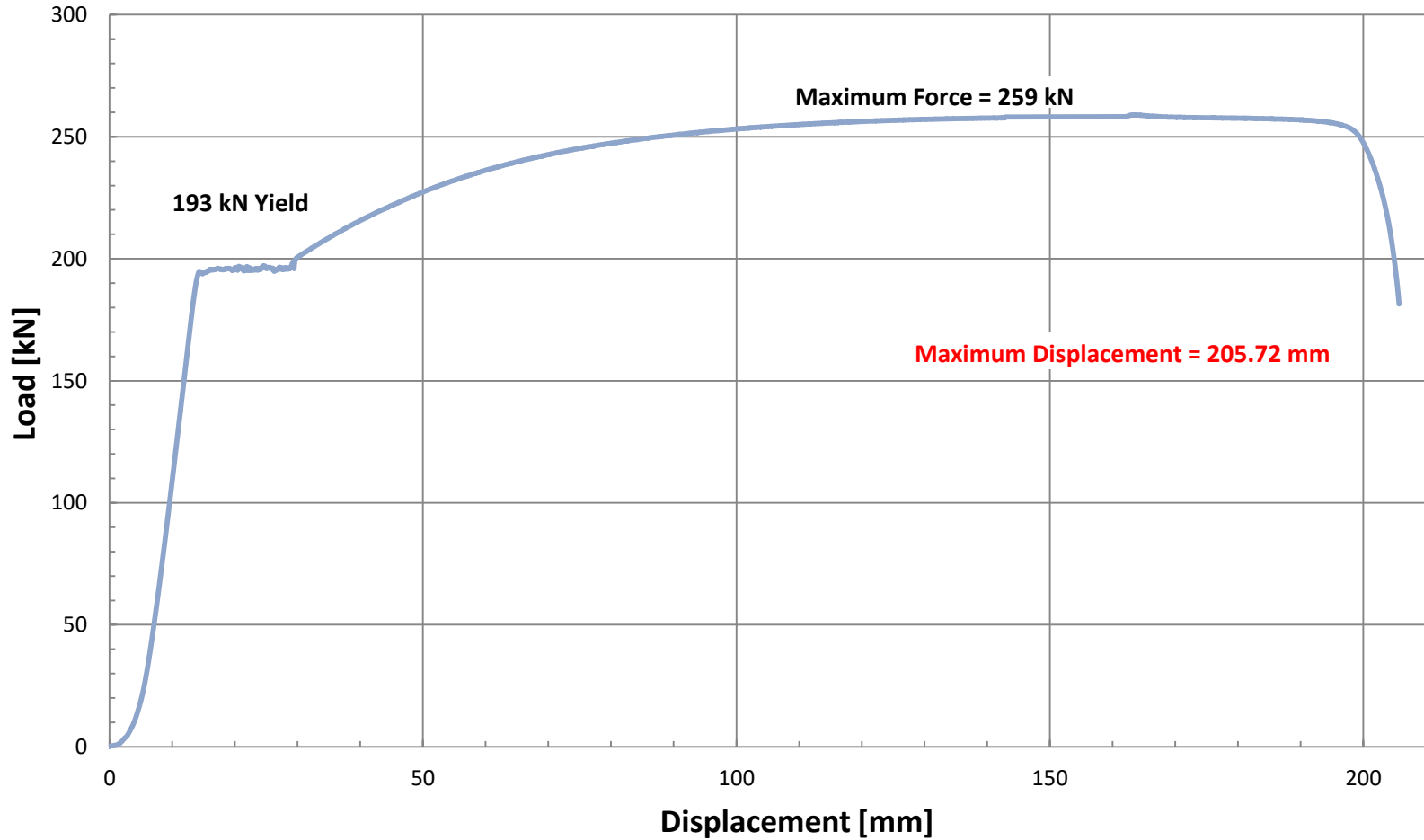
General Specifications	20 mm VersaBolt	22 mm VersaBolt
Dynamic Capacity	Split Tube *	Split Tube *
Canmet Testing	<i>37 kJ</i>	> 50 kJ

\* As tested by Canmet



# Static Behaviour

## 22 mm VersaBolt™ 1 Metre Smooth Bar Section

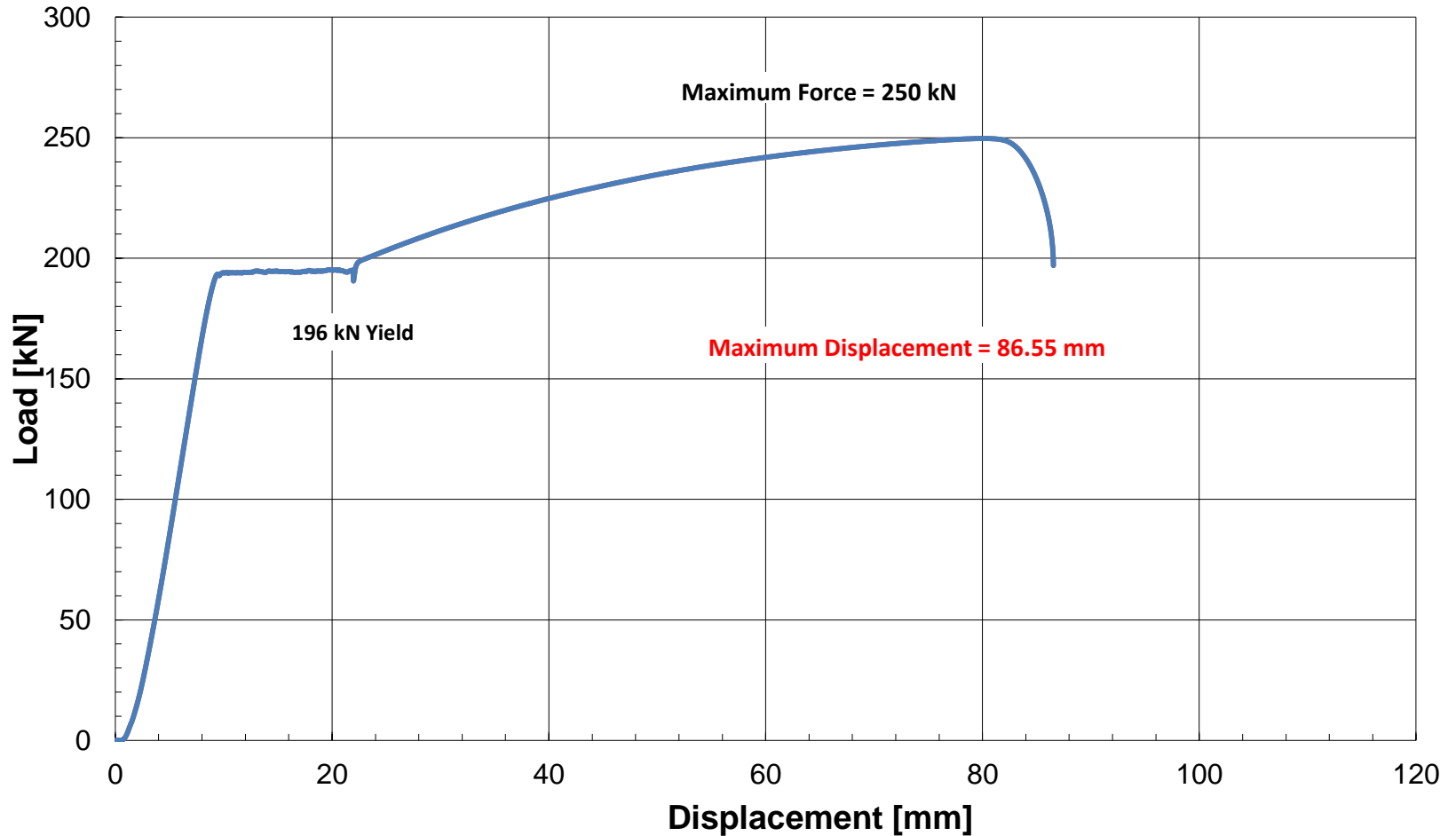


# 22mm Split Tube Static Testing



# Static Behaviour

## 22mm VersaBolt™ Threaded End Test

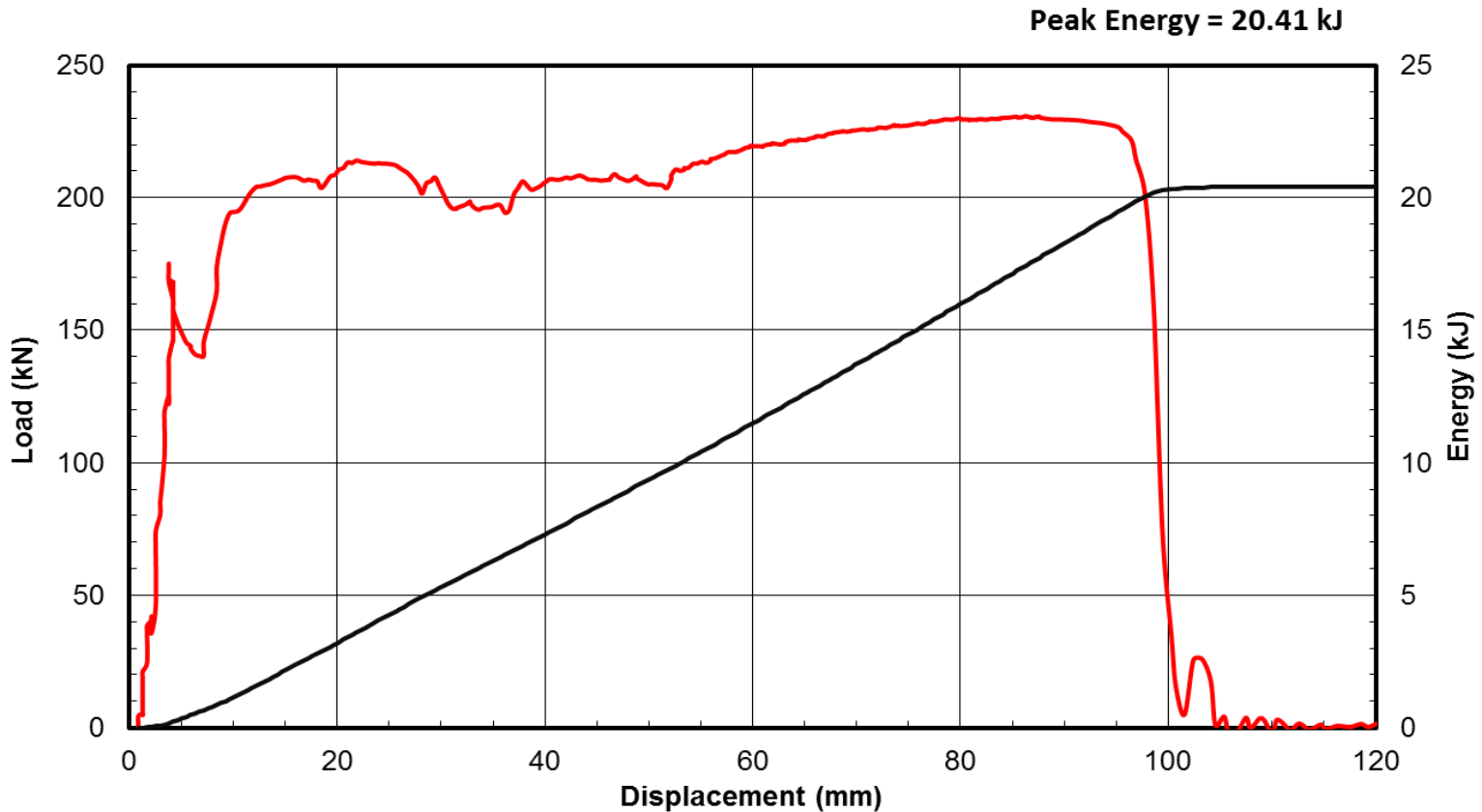


# 20mm VersaBolt™ 20 kJ

## Dynamic Drop Test

Specimen VersaBolt-33 Grade 65 Drop 1  
Mass = 1560.85 kg; Height = 1.5 m  
Energy = 22.97 kJ; Velocity = 5.42 m/s

— Plate Load — Absorbed Energy



# 20mm VersaBolt™ 40 kJ

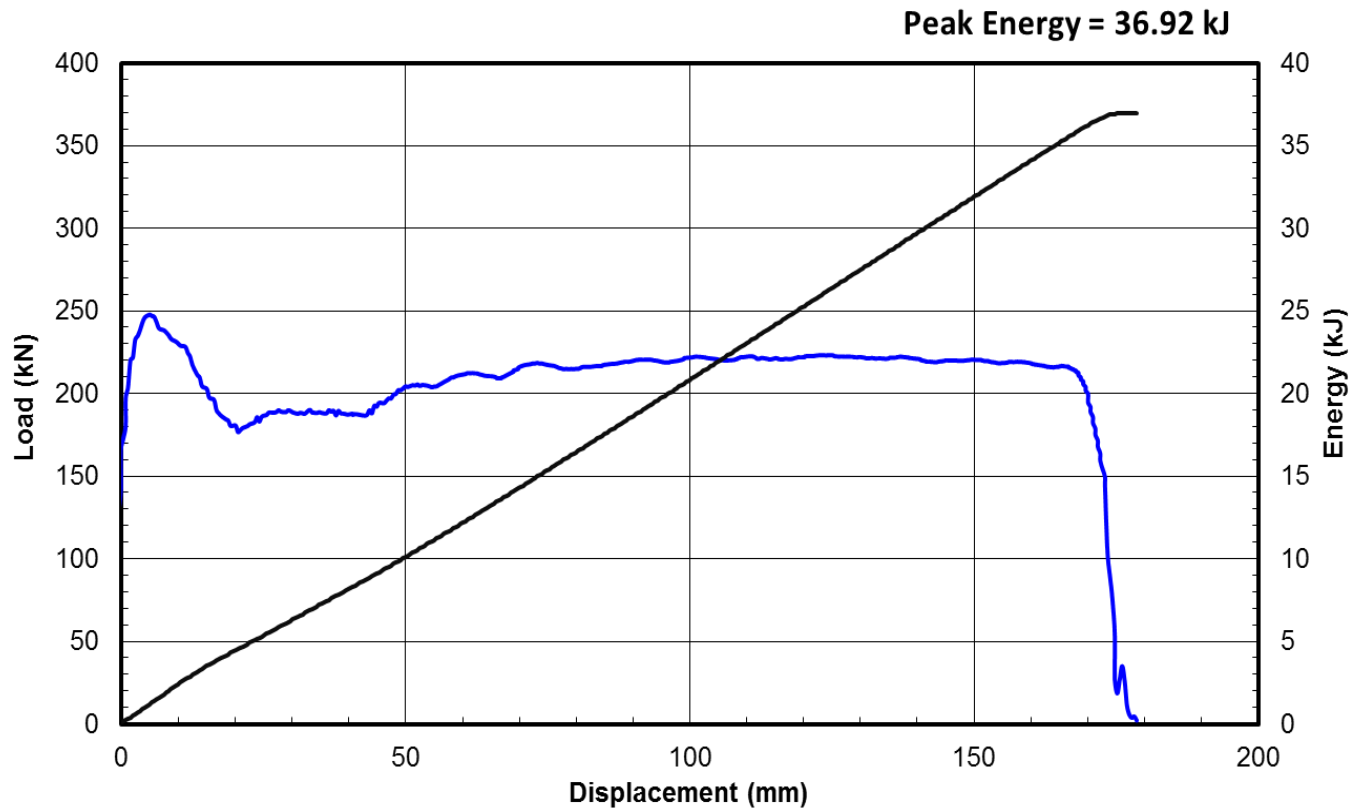
## Dynamic Drop Test

Specimen VersaBolt-32 Grade 65 Drop 1

Mass = 2674.6 kg; Height = 1.5 m

Energy = 39.36 kJ; Velocity = 5.42 m/s

— Impact Load — Absorbed Energy

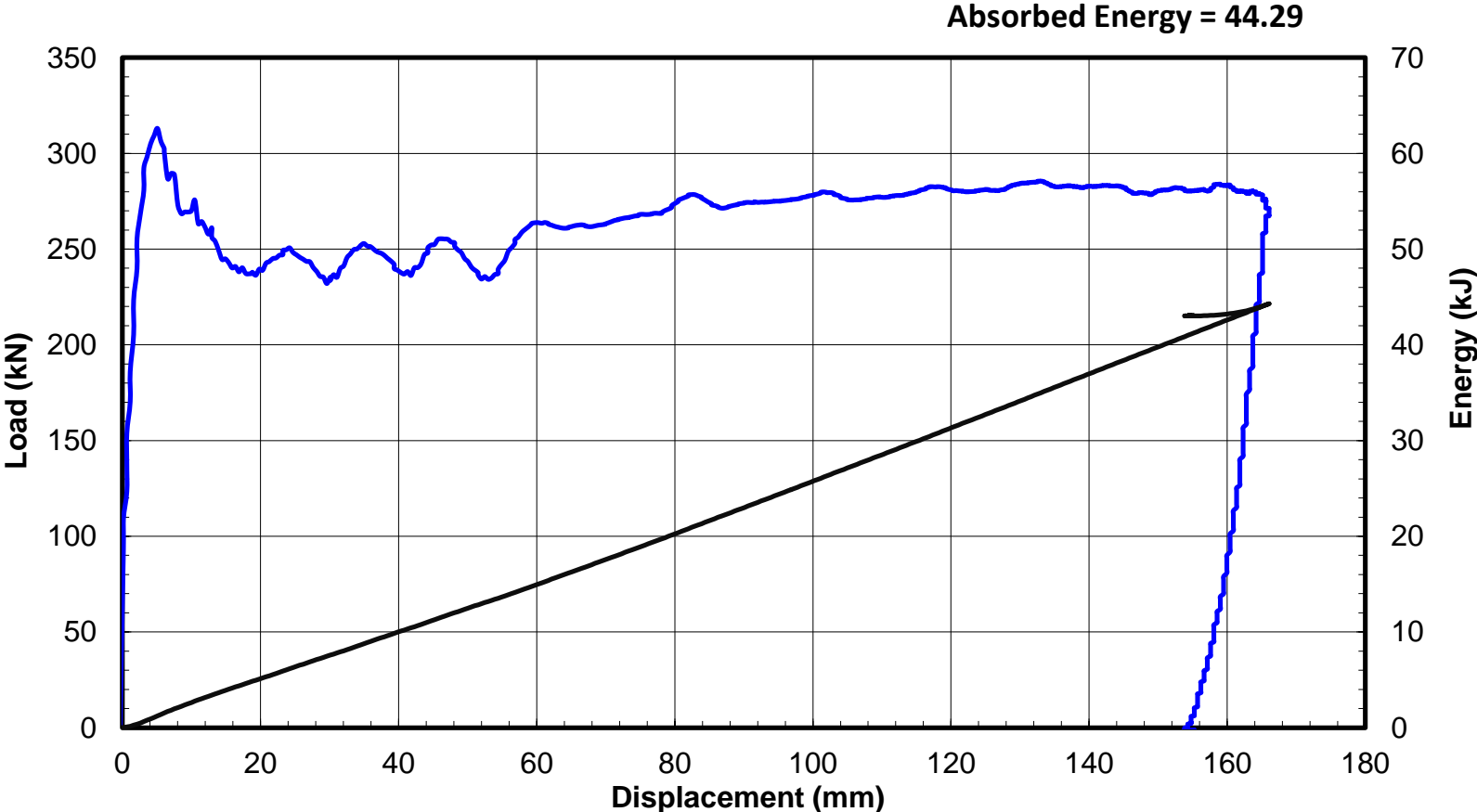


# 22mm VersaBolt™ 42 kJ

## Split Tube Drop Test, 1.5 Metre Anchor Spacing

Specimen Versa-2 Drop 1  
Mass = 2897 kg; Height = 1.5 m  
Energy = 42 kJ; Velocity = 5.42 m/s

— Impact Load — Absorbed Energy

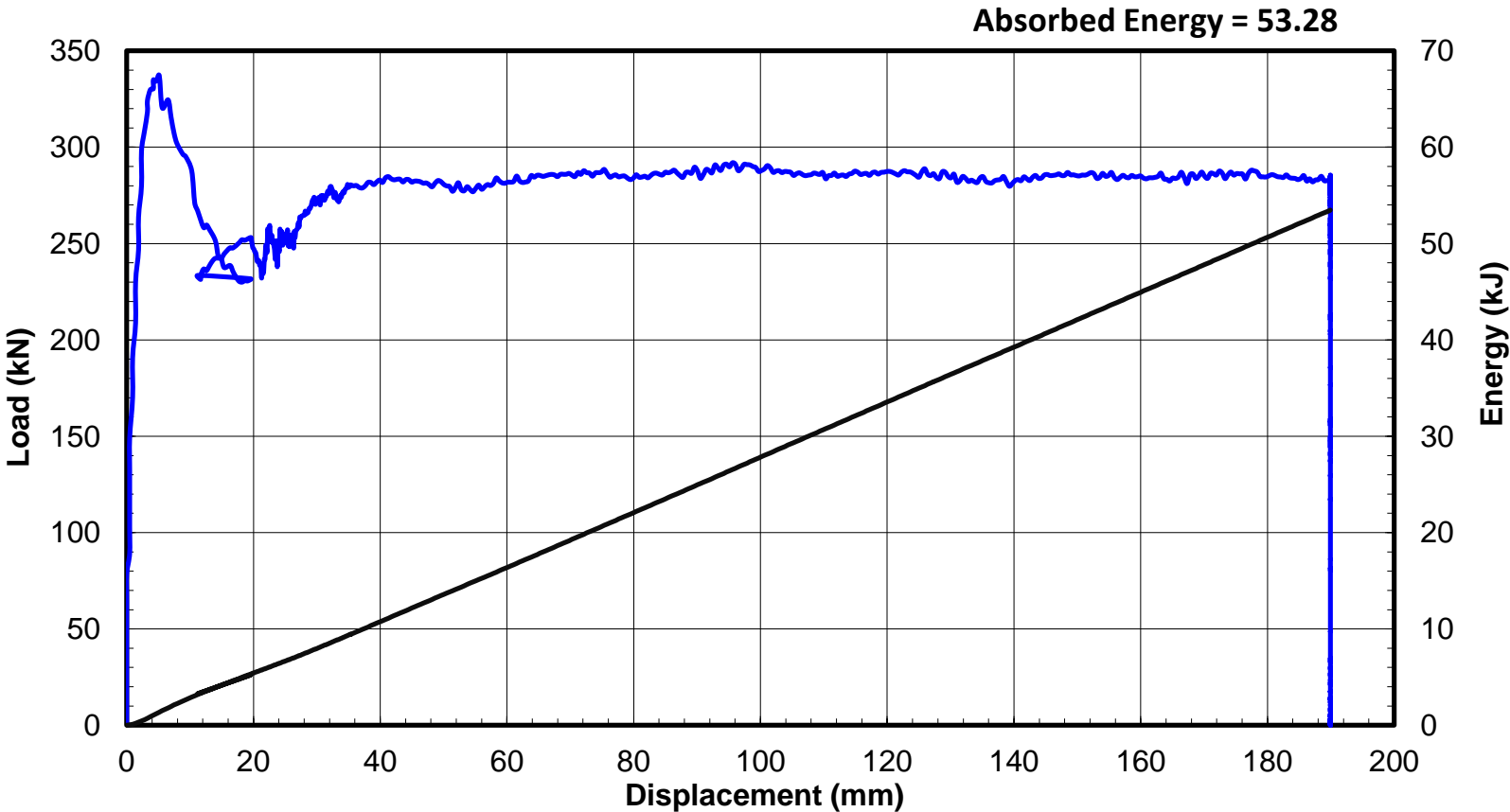


# 22mm VersaBolt™ 50 kJ

## Split Tube Drop Test, 1.6 Metre Anchor Spacing

Specimen Versa-3 Drop 1  
Mass = 2897 kg; Height = 1.76 m  
Energy = 50 kJ; Velocity = 5.88 m/s

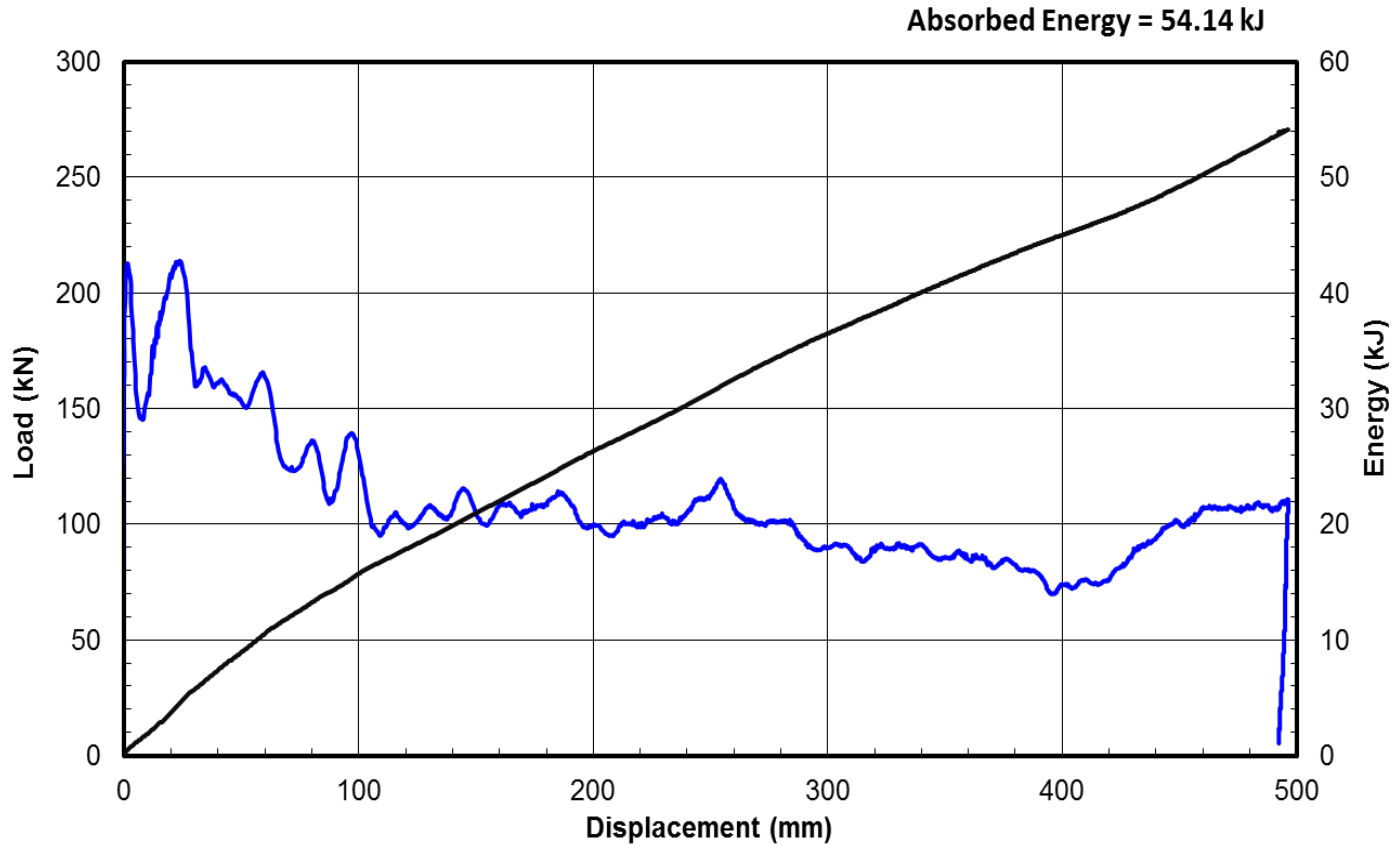
— Impact Load — Absorbed Energy



# 22mm 40 kJ Drop Test in 38mm Pipe

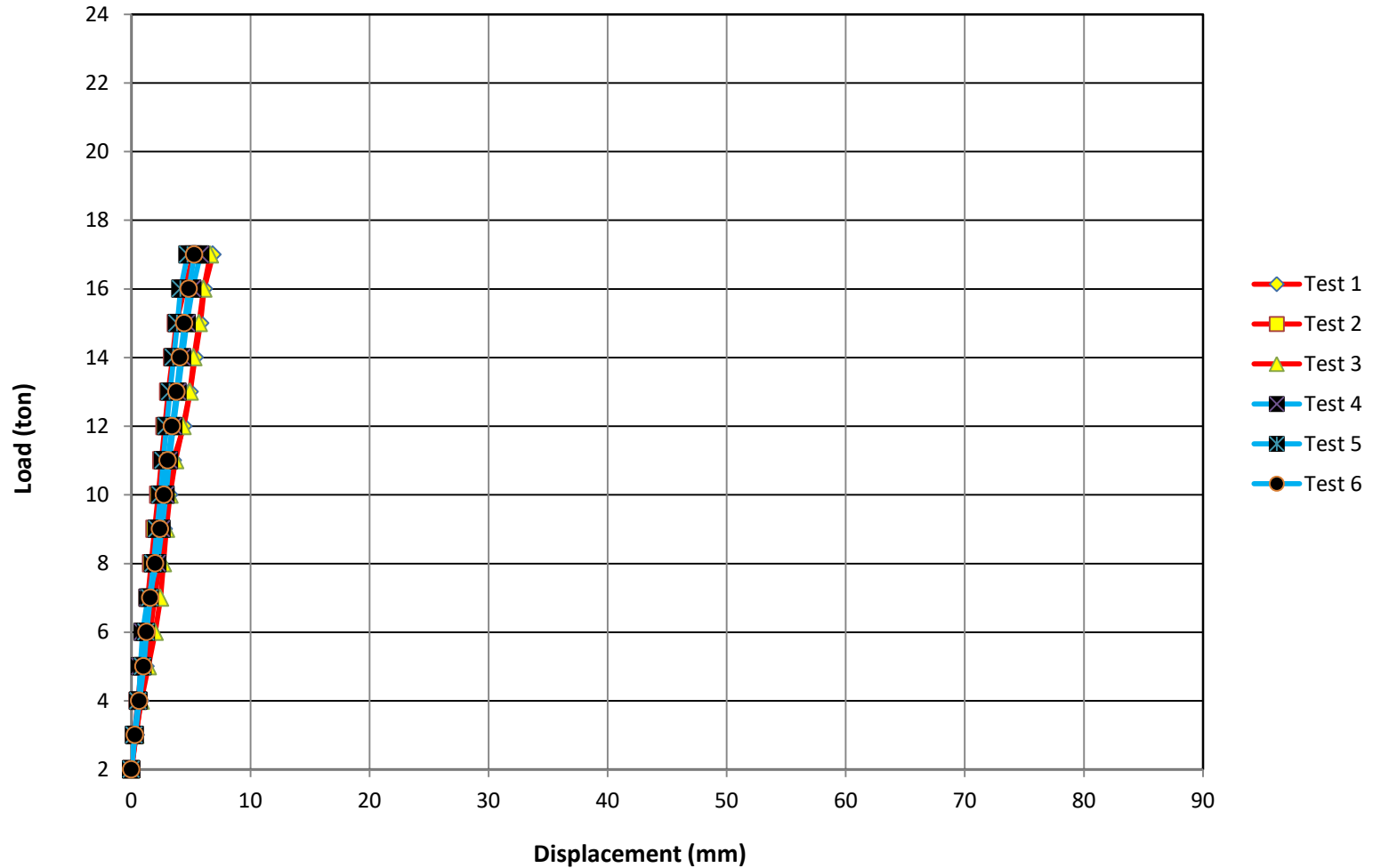
Specimen Versa-6 Drop 1  
Mass = 2897 kg; Height = 1.41 m  
Energy = 40 kJ; Velocity = 5.26 m/s

— Impact Load — Absorbed Energy



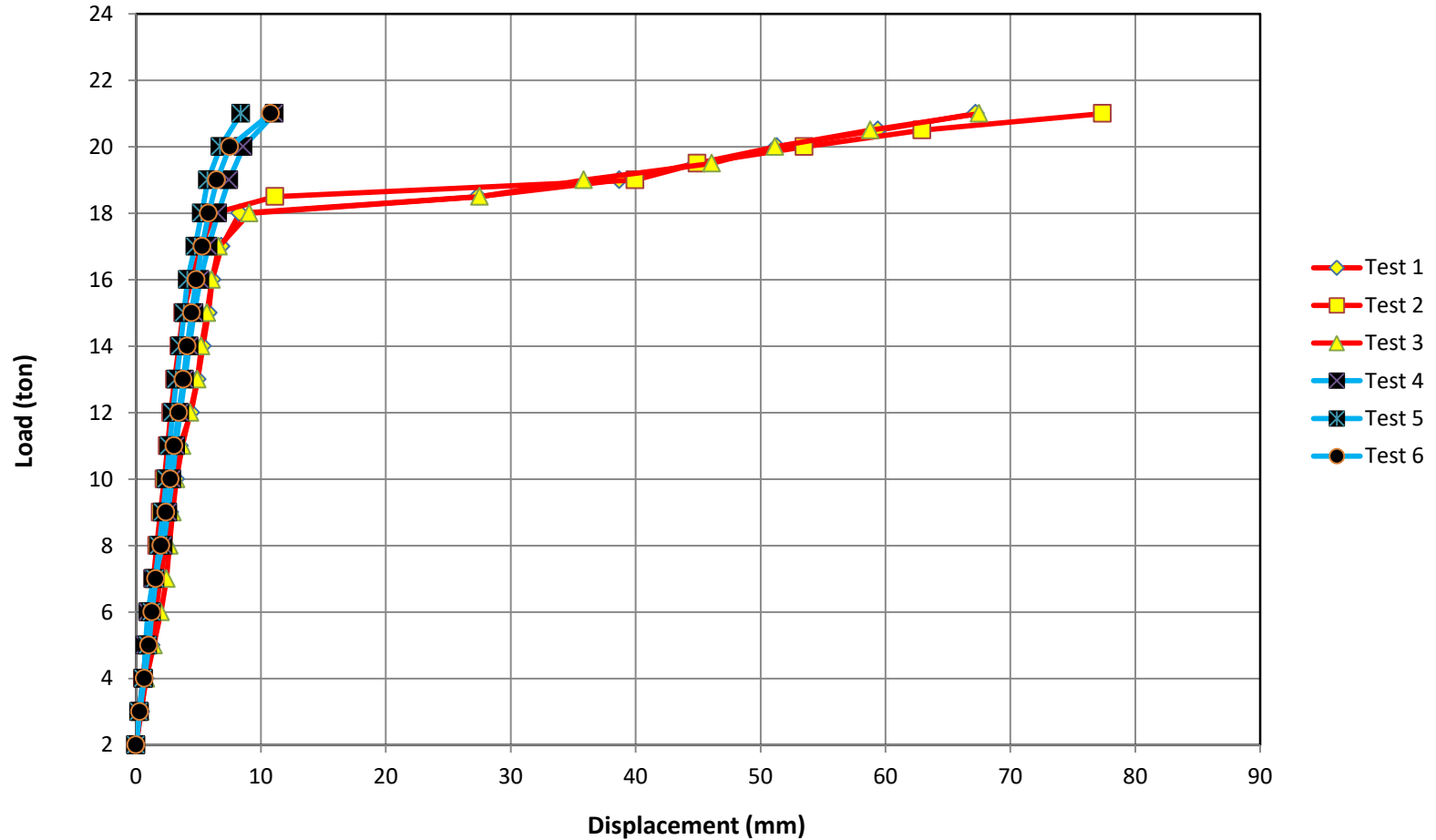


# 20mm x 7' VersaBolt™ Pull Test



# Point Anchor Versus Full Encapsulation Pull Test

20mm x 7' (2.1m)



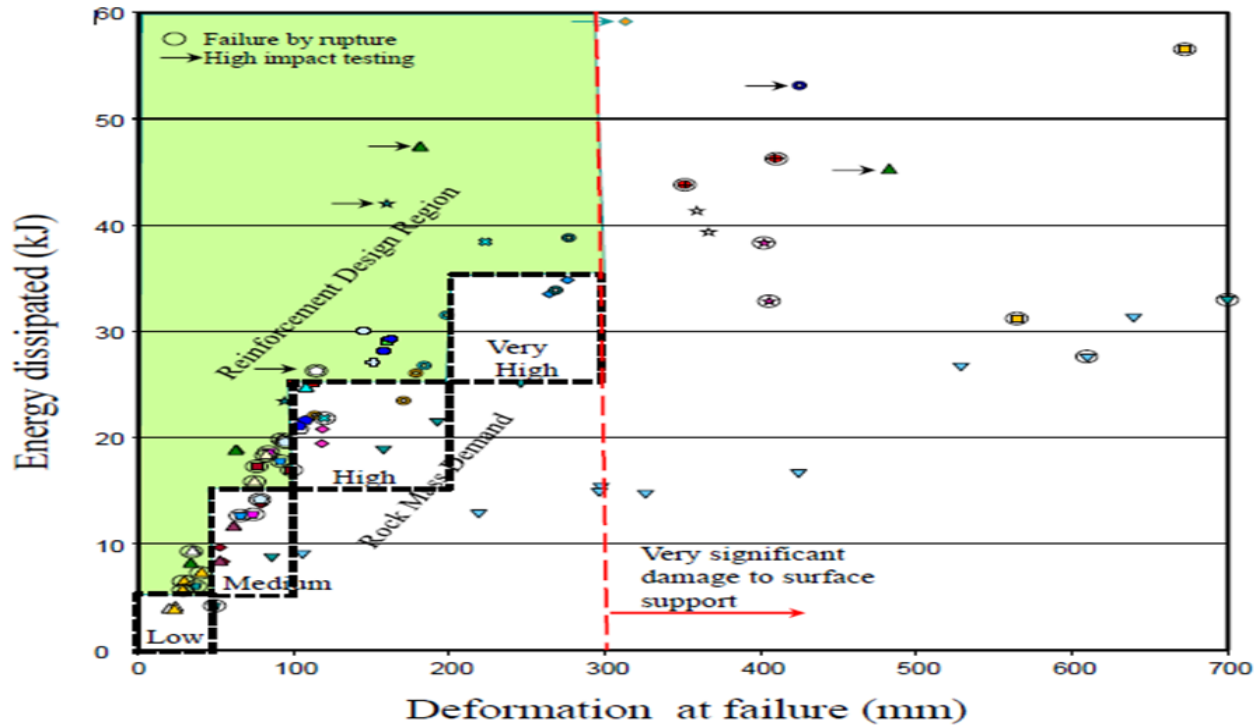
# Static Behaviour

- Rebar is considered a very stiff support, assuming it is fully encapsulated and won't allow much rock displacement before either the threaded section or the encapsulated bar breaks.
- Ground support requirements change over time. Initially the rock may be self supporting however as mining progresses and stress increases, the rock mass may change to a "broken" rock mass followed by failure due to overstressing .
- The VersaBolt™ behaves similarly to any other fully encapsulated bolt up until the yield point of the steel is reached, with relative displacement of only 6 to 8mm. It should be noted that the steel yield point of a 20mm VersaBolt™ is approximately 18 tons (160 kN) which is slightly less than the ultimate tensile strength of a 20mm rebar.
- A two anchor design would be sufficient stiff for most mines initial static requirements however over time as stresses increase the bolt will have the capacity to deform accordingly.
- When squeezing ground is the primary consideration, a two anchor would definitely be better suited than a three anchor design.
- VersaBolt™ however can be configured to provide more or less total displacement by varying the number of anchors, bolt length of the support or increasing the diameter of the steel.
- Canmet's static testing of a smooth bar section versus an equal length threaded bar section demonstrates the importance of having the collar anchor encapsulated so that the overall elongation potential of the steel is maximised.

# Dynamic Stiffness

- Dynamic stiffness is the amount of deformation or displacement you get from a given energy input. Rebar would be considered to have a high dynamic stiffness, lower is better.
- As the energy input increases, so to does peak and average loading
- A longer smooth bar section between the anchors results in higher elongation for a given energy input which results in lower overall average loading of the steel
- The VersaBolt relies on steel stretch to absorb energy and steel stretch doesn't occur until the yield point of the steel is reached. Making a bolt larger simply increases the stress level at which the bolt starts to stretch.
- The surface support will always be subjected to the energy of a rockburst. Generally the first metre of rock is what will be ejected and needs to be contained while the energy is transferred to the bolt.
- It is conceivable that we could make a bolt with an energy absorption capacity of 100 kJ yet the overall support would fail during a rockburst for the simple reason it is too stiff dynamically i.e. didn't displace sufficiently.
- The surface support needs to be strong enough to transfer this energy to the without it failing, hence why it is important that which ever support is used, the surface support is equal to the task.
- The easiest way to reduce the dynamic stiffness of a VersaBolt, is to eliminate the central anchor so that it allows more displacement for a given input energy.

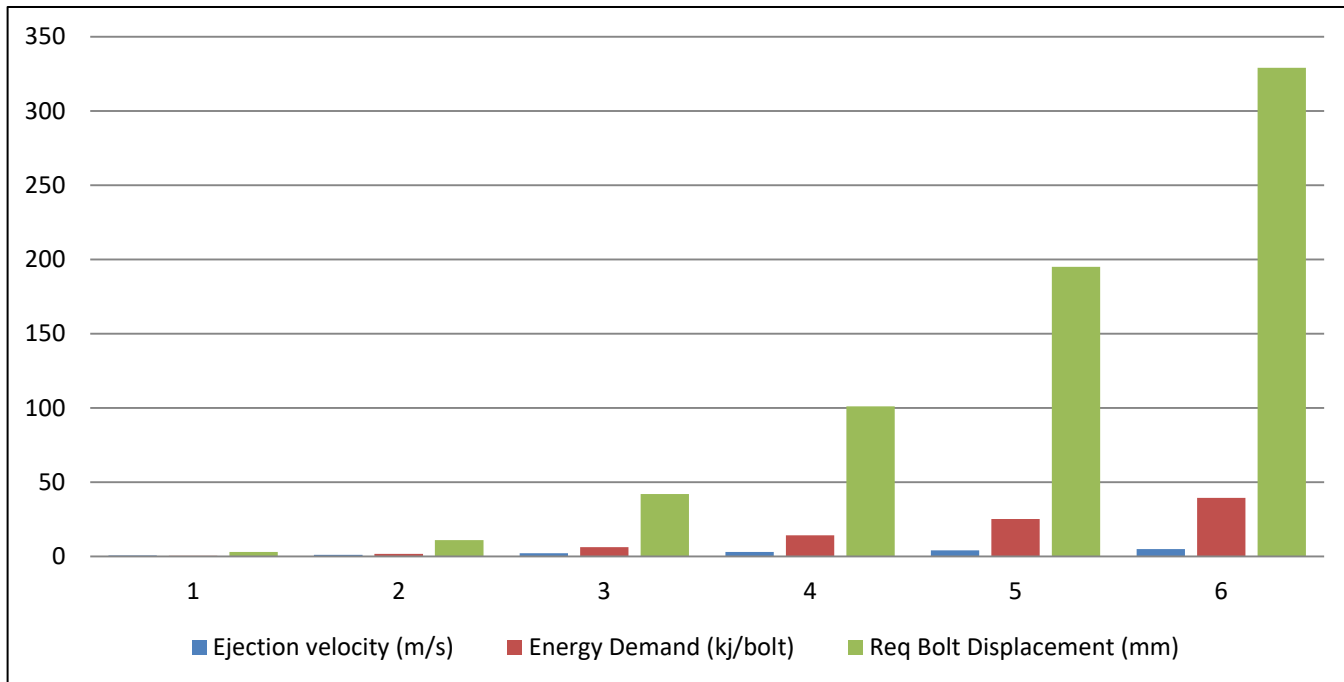
# Typical Rock Mass Demand For Ground Support Design



Demand category	Reaction pressure (KPa)	Surface displacement (mm)	Energy (kJ/m <sup>2</sup> )
Low	<100	<50	<5
Medium	100 -150	50 -100	5 -15
High	150 -200	100 -200	15 -25
Very High	200 -400	200 -300	25 -35
Extremely High	>400	>300	>35

# Dynamic Support Calculation For A 1 Metre Depth Of Failure

Mass (kg/bolt)	Ejection velocity (m/s)	Energy demand (kJ/bolt)	Req bolt displ (mm)	Est bolt yield (kN)	Bulking rating	Bolt stability rating
3150	0.5	0.4	3	150	Low	Stable
3150	1.0	1.6	11	150	Low	Stable
3150	2.0	6.3	42	150	Medium	Stable
3150	3.0	14.2	101	140	Medium	Stable
3150	4.0	25.2	195	130	High	Stable
3150	5.0	39.4	329	120	Extreme	Unstable

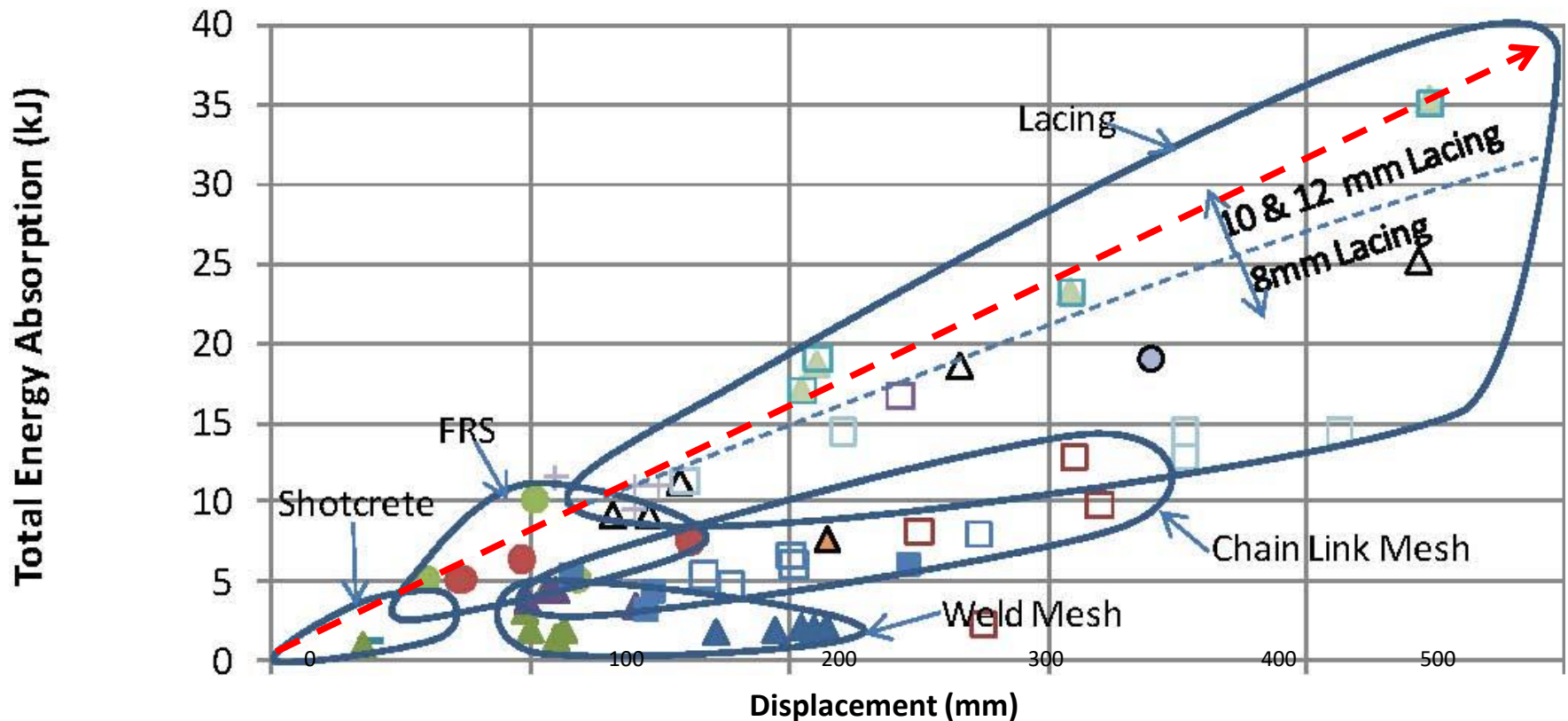


# Surface Support

- Bolts behave differently under dynamic and static loading.
- The connection between the bolt and screen fails in 75-80% of the time in large rockburst events (as previously published by Brad Simser)
- The ejected blocks from the rockburst strip the mesh from the bolts and very often, the bolts are still intact.
- You will note where the arrows are pointed, the plates on these bolts aren't even deformed which suggest they did not absorb any energy what so ever.



# Dynamic Capacity Of Various Surface Support



- **Compilation of drop tests performed on various surface support elements and reported by the following authors; Kaiser et al. (1996) (K); Ortlepp and Stacey (1997) (O); Player et al. (2008b) (P)**



# Dynamic Stiffness and Surface Support Capacity

- Every bolt design has varying static and dynamic stiffness
- Surface support needs to be matched to the dynamic behaviour of the bolt.
- The surface support also needs to match the anticipated energy demand that it will be subjected too.
- As energy input increases, the bolt displacement need to increase exponentially
  - A dynamically stiff bolt will require a stronger and more flexible surface support so that it survives a seismic event
  - Conversely, if the bolt has a lower dynamic stiffness, the surface support will not be subjected to the same loading
- Energy absorption in kJ is not the only consideration when evaluating a bolt design, overall behaviour is as important

# Comments & Conclusions

- Ground support requirements change over time. Initially the rock may be self supporting however as mining progresses and stress increases, the rock mass may change to a “broken” rock mass followed by failure due to overstressing .
- A VersaBolt™ would be sufficient stiff for most mines initial static requirements however, over time as stresses increase, the bolt will have the capacity to deform accordingly.
- Due to the stiff behaviour of the steel up to the yield point, the VersaBolt™ can be considered a rigid support even with only two anchors
- A larger diameter bolt is better for squeezing ground but not necessarily for dynamic energy absorption since the steel doesn't start to absorb energy until the yield point of the steel is exceeded.
- We can make a bolt with a 100 kJ capacity however if the bolt can't displace or elongate sufficiently, the rock and the surface support will fail.
- Bolt spacing can be modified to match the anticipated energy demand and displacement.
- The two anchor bolt design, with the longer centre smooth bar section, will allow much more displacement in squeezing ground conditions and when subjected to a seismic event, the longer smooth bar section in the centre will also reduce the dynamic stiffness of the bolt.
- Last but not least, the collar anchor should always be encapsulated with resin to ensure that in the event of a rockburst, the first metre of rock being ejected is well anchored to the bar and can transfer the load the next anchor point



Thank You For Your Time