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Use of Yield-Lok bolts as conveyor belt hanging system in seismic areas

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Abstract

This paper introduces the use of Yield-Lok bolts as hanging conveyor belt system in Barrick Gold's Pascua-Lama Project in Chile, in considering the dynamic loads resulting from earth quake seismicity. A 4 km tunnel and hanging conveyor belt system are in construction in the seismically active area between Chile and Argentina. In addition to the static load of the conveyor belt and material live weights, seismic loading resulting from an earth quake is considered in the design of hanging system with 50 years of service life. Dynamic yielding bolts are therefore employed to prevent the conveyor belt from falling to the ground. Based on results from a series of pull tests on site and dynamic tests in laboratory, Yield-Lok bolt developed by Jennmar has been selected as the dynamic yielding hanging system due to its consistent performance and high capacity of energy absorption.

In this paper, the tunnel project and ground conditions are introduced; the design criteria of the dynamic yielding hanging system is discussed; and results of site pull tests and laboratory drop tests with the Yield-Lok bolts are presented.

1 Introduction

A 4 km tunnel is in construction at Barrick Gold's Pascua-Lama Project, crossing the mountains between Chile and Argentina, to set a suspended conveyor belt that will transport ore from the primary crusher in Chile to Argentina for mineral processing. The facility has the design capacity of 45,000 tpd and a service life of 50 years. The suspended conveyor belt system is selected instead of pedestal placement for the consideration of significant time and cost saving. Besides, the suspended belt system is expected to require less maintenance due to the following assumptions:

- continuous clearance under the belt (no pedestals resting on floor)
- greater adjustment ability (vertical and lateral)
- no impact on system from water flow on floor of tunnel.

In view of the fact that the tunnel is located in a seismic/earthquake active area, however, dynamic loading from an earthquake or seismic is considered in the design of hanging system, in addition to the dead weight load of the conveyor belt and the live load of the ore. To prevent the conveyor belt from failing from its support and falling to the ground, resulting in the extreme case of a strong seismic event, the bolts to be used for the hanging system should not only be strong enough to take the total static and dynamic loads, but also be yieldable when the system is subjected to extreme dynamic loads.

A systematic study was conducted to select a technically reliable and cost effective yielding bolt, including a series of site pull tests and a comparative study of different kinds of bolts. The Yield-Lok bolt, developed by Jennmar of Canada, has been selected as the preferred support system for the conveyor belt. The bolt is characterised by:

- consistent performance under static and dynamic conditions
- large energy absorption capacity

- broad application with various grouting materials
- easy installation
- cost effectiveness.

In this application, the 3 m Yield-Lok bolt is specified. The bolt is installed in 33 mm drill hole and grouted with pumpable resin or cartridges.

This paper summarises the rock quality of the tunnel, the design criteria of the hanging conveyor belt system, and the static and dynamic performance of Yield-Lok bolts.

2 Conveyor belt tunnel and dynamic yielding hanging system

At Barrick Gold's Pascua-Lama Project, a 4 km conveyor tunnel is in construction, crossing the continental divide between Chile and Argentina (Figure 1).

The tunnel is being excavated through hard granite. The overall rock mass quality is fair to very good except through a few fault zones. The average RMR is between 60 and 80. The tunnel size is 5.5 x 6 m. Resin rebar and fibre reinforced shotcrete are employed as the main ground support. The ground support pattern is summarised as:

- shotcrete – synthetic fibre reinforced at 50 mm thickness
- resin rebar – 22 mm diameter x 2.4 m long at 1.2 x 1.2 m pattern
- steel set – only in poor rock mass exposures.

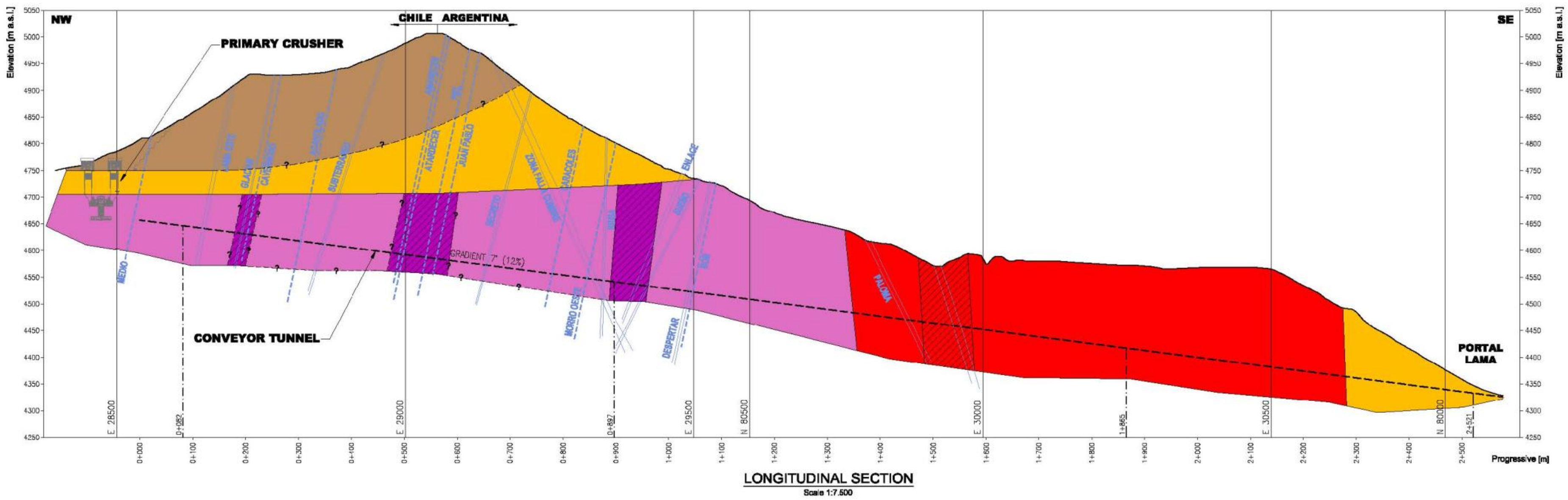
The suspended conveyor belt is designed as the main transportation system to deliver ore to the mineral processing plant. In view of the fact that the tunnel is located in a seismically active area, seismic loading is considered in designing the hanging system. Thus, there are three kinds of loads that may potentially act on the support system, as indicated in Figure 2, including:

- the dead load of the structure and belt weight
- the material live load
- the seismic load.

Based on the design of two bolts for every three meters, the dead load and material live load applied on each bolt will be 4.5 kN and 4.0 kN, respectively. Referring to seismic engineering recommendations, a load factor of 1.5 will be used for seismic loading on the system. Thus, the total load acting each bolt is approximately 12.75 kN or roughly 1.3 t.

In considering the service life of 50 years, the hanging system should be not only strong enough to take all of the loads at a specified minimum safety factor, but also be yieldable in the extreme case that the system experiences a very large seismic event. Thus, a dynamic yielding bolt has been selected as the hanging system of choice. The selection of a suitable dynamic yielding bolt is based on the following criteria:

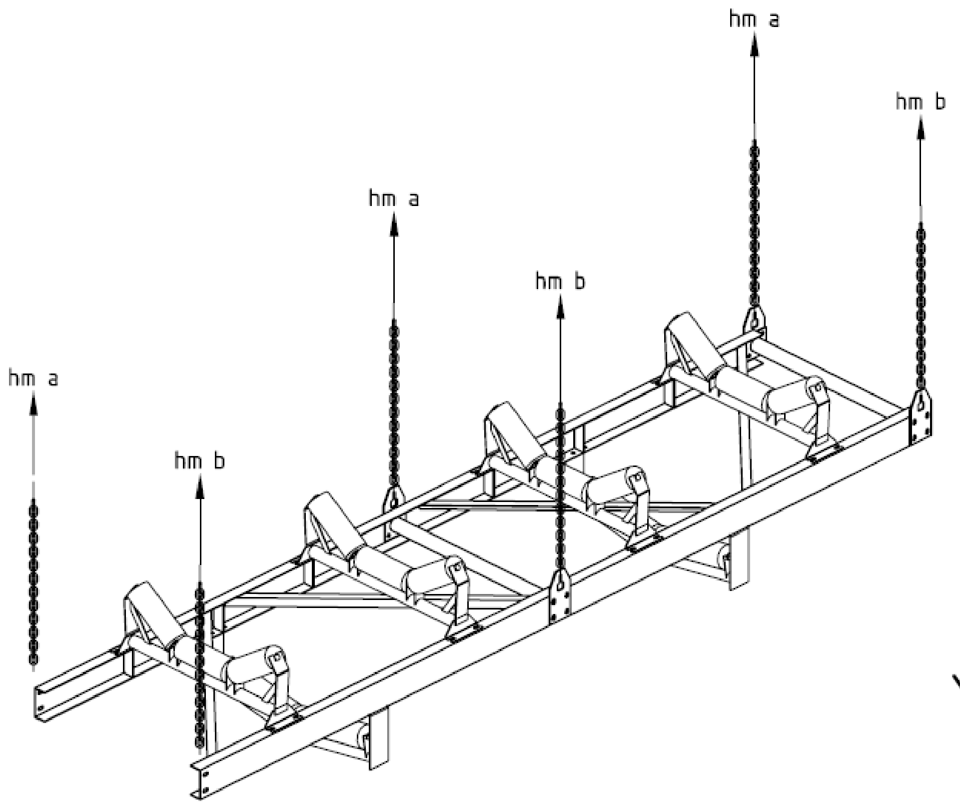
- high static steel strength
- consistent and reliable dynamic yielding performance
- corrosion protection capacity for 50 years service life
- easy installation with existing equipment and experience
- cost effective.



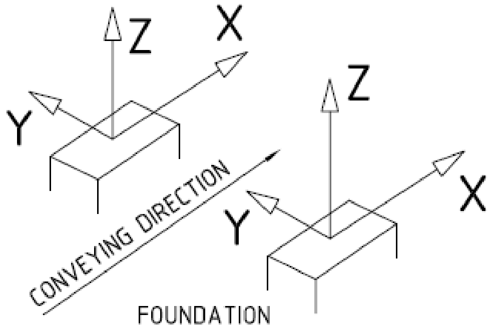
Average Rock Mass Parameters for the Crusher Area				
Parameter	Dacitic/Rhyolitic Lapilli Tuff	Dioritic stock	Dacitic breccia tuff	Fault zone
RMR	74 ± 10	70 ± 7	73 ± 10	62 ± 5
UCS (MPa)	25 ± 5	40	72 ± 30	60
m_i	15	15	33	18

Average Rock Mass Parameters for the Tunnel					
Parameter	Pascua lama intrusive complex		Dioritic stock	Dacitic breccia tuff	Fault zone
	Remote	Close			
RMR	80 ± 3[a]	56 ± 8[b]	71 ± 7	57 ± 18	24 ± 4[c]
UCS (MPa)	72 ± 30[d]	80 ± 25	72 ± 30[d]	32	20[e]
m_i	33	33	28	15	33

Figure 1 Longitudinal section of geology and rock quality



Foundation Loads hanging module	Action Loads without any factor								
Foundation No Location	Dead Load DL [kN]			Material live load LLn [kN]			Seismic Load [kN] Ev +/-Z		
	X	Y	Z	X	Y	Z	X	Y	Z
CV 02 hm a			-5,0			-4,0			+/-2,5
CV 02 hm b			-5,0			-4,0			+/-2,5



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- ☐ APPROVED AS NOTED
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Figure 2 Structure of suspended conveyor belt system

Product comparison study and testing were conducted. The dynamic bolts based on mechanical yielding devices (Varden et al., 2008; Haven and Ozbay, 2009) were eliminated due to the rusting potential of mechanical yielding components during the specified life of service. Since the Yield-Lok bolt (WIPO, 2011), uses an engineered polymer as its yielding device, its properties and performance are stable for a long time. The Yield-Lok bolt satisfies all of the requirements specified above.

3 Introduction of the Yield-Lok bolt

The Yield-Lok bolt was developed by Jennmar of Canada for ground support in rock prone to rockburst conditions (Wu and Oldsen, 2010). As illustrated in Figure 3, the bolt is made of 17.2 mm diameter, grade 75 round steel bar. The typical yield and ultimate tensile strength of the bolt is 15 and 20 t, respectively. The steel bar is upset to specified dimensions at one end and partially or fully encapsulated in an engineered polymer coating to achieve designed yielding performance under dynamic loading. The end profile of polymer coating is angled to aid insertion of the bolt. Also the mixing/centering paddles, longitudinally spaced over the length of the coating, provide shredding of the resin cartridge packaging. The other end of the bar is threaded for tensioning with a nut. A dome plate and spherical washer are used for angle compensation and to load the bolt axially. The bolt is tensioned and provides immediate primary support on installation. Under dynamic loading conditions, the upset transfers the impacts on the surrounding polymer coating, resulting in confined compression, thermal softening and flow of the polymer around the upset, creating the plowing effect. The dynamic energy is therefore dissipated by pulling or plowing the upset through the polymer. Part of the dynamic energy is consumed in the friction between the smooth bar and the polymer coating.

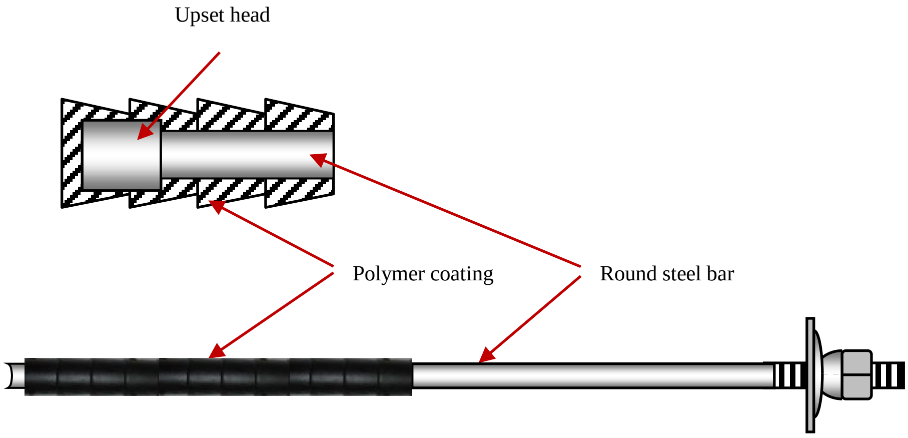

Figure 3 Design and components of the Yield-Lok bolt

4 Static performance of the Yield-Lok bolt

Under static loading conditions, the wall of drill hole and resin provides confinement to the polymer, producing anchorage against the upset. The Yield-Lok bolt performs similar to a point-anchored rebar bolt, providing stiff reinforcement and containment of the rock mass. Figure 4 summarises results of a series of pull tests conducted with Yield-Lok bolts installed in various hole sizes between 33 and 38 mm with fully encapsulated resin. As can be seen, the samples consistently yielded at the nominal steel yielding strength of 15 t. In Pascua-Lama granite, 3 bolts were installed in 33 mm drill holes, grouted with pumpable resin. All 3 samples were pull tested to 15 t when the steel started yielding. It is understand that with good installation methods and quality, the Yield-Lok bolt performs similarly to a rebar bolt.

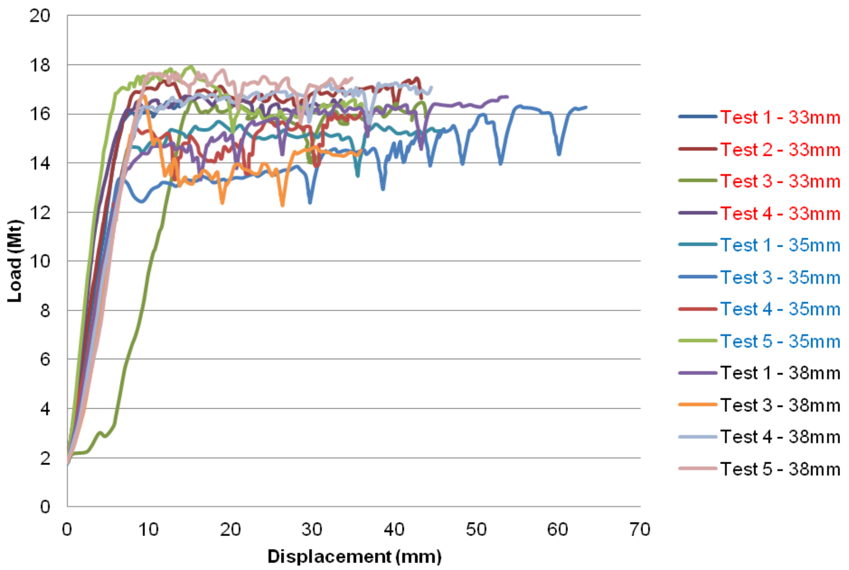

Figure 4 Pull test results of Yield-Lok bolts installed in various hole sizes

5 Dynamic performance of Yield-Lok bolt

A number of dynamic drop tests were conducted at the CANMET test facility in Ottawa, Canada to test the dynamic performance of the Yield-Lok bolts.

The drop test method attempted to simulate a dynamic load condition similar in amplitude and velocity to a rockbursting event. This test protocol has been established as a benchmark test used in the development of other types of yielding supports (ASTM D7401-08 (2008)). Boreholes were simulated by 12 mm thick steel tubes with an internal diameter of 34.5 mm. The steel tube preparation included a slight roughening of the inside surface over approximately the last meter. This roughened section was referred to as the top of the tube where the bolt is grouted with resin.

Similar to rebar installation on site, the tube was first loaded with resin cartridges. A bolt of 1.8 m length was then slowly spun into the tube at a steady advancement rate. Once the bolt reached the bottom, the advancement was stopped and the bolt was rotated at full speed (220 to 350 rpm) for an extra 5 seconds to fully mix the resin.

Figure 5 Drop test equipment and configuration at CANMET, Ottawa

Drop tests were conducted in the drop test rig of 3 t capacity and 2 m height (Figure 5). As recommended in the ASTM standard for dynamic tests (ASTM D7401-08 (2008)), a drop weight of 1,115 kg and drop height of 1.5 m were used to produce the loading speed of 5.4 m/s and an input energy of 16.4 kJ. To study the maximum energy absorption capacity, a weight of 3 t and 1.5 m drop height were tested to simulate the input energy of 42.6 kJ.

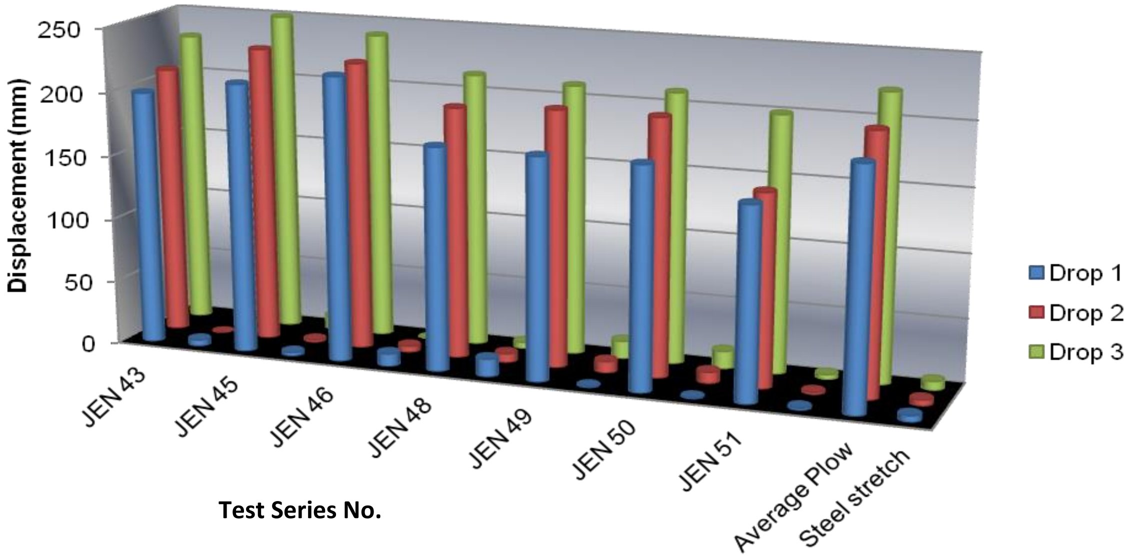

Figure 6 Dynamic tests with standard energy input of 16.4 kJ (m = 1.115 t, H = 1.5 m)

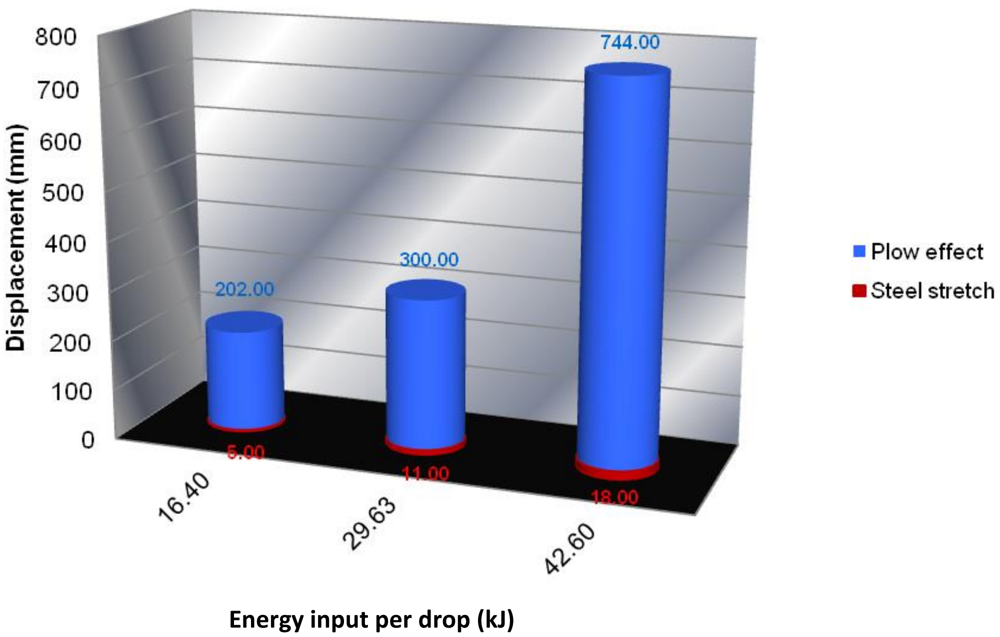

Figure 7 Dynamic tests with various energy inputs

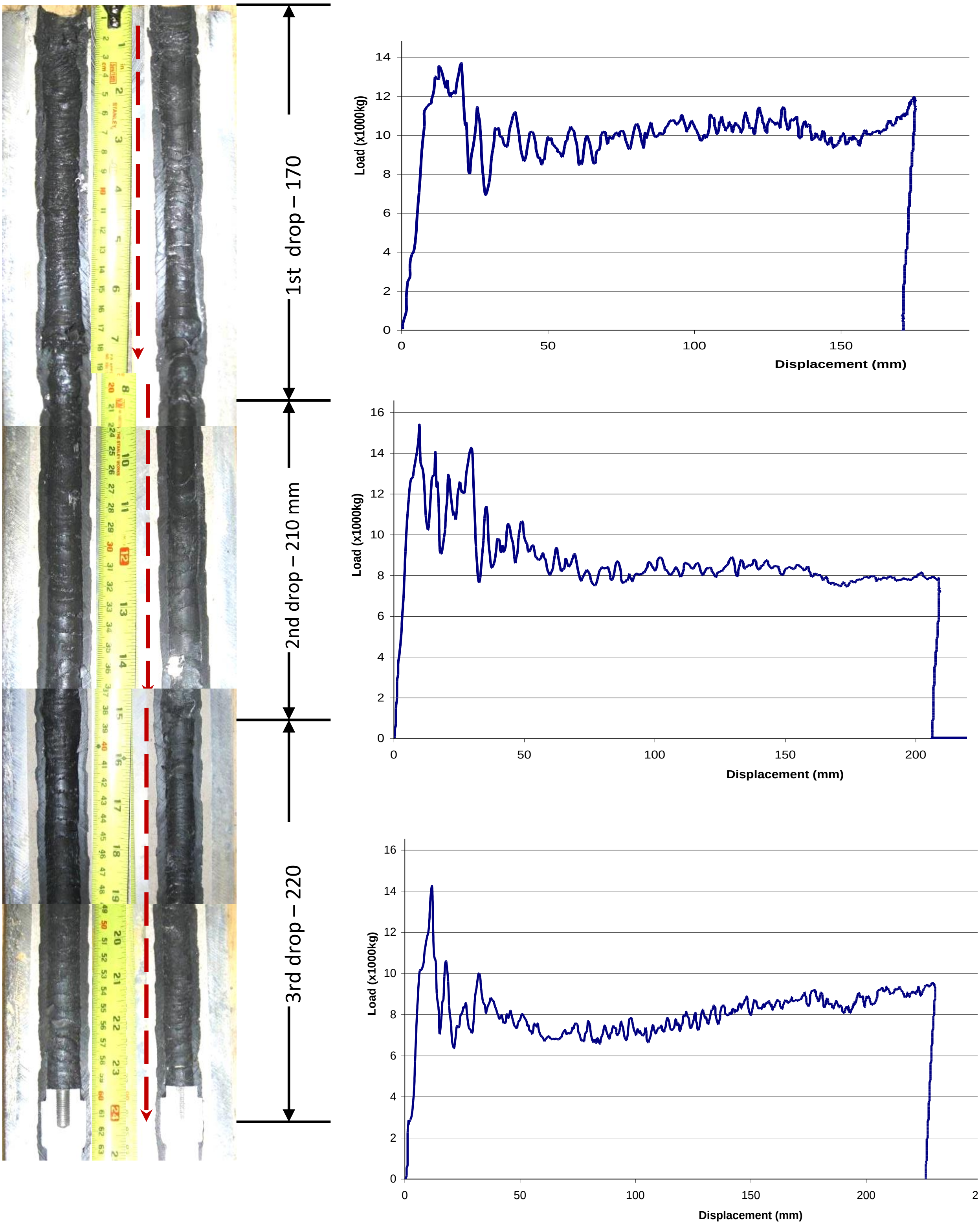

Figure 8 Typical testing results from Sample Jen-50

Test results from standard energy input and various energy inputs are summarised in Figure 6 and 7, respectively. As indicated, the bolts consistently yield at around 200 mm displacement at 8 to 10. Most of the input dynamic energy (96%) is consumed in ploughing the upset through the polymer, while only 3–4% of the energy is consumed in steel elongation.

Typical test results are presented in Figure 8. On the left is the autopsy of polymer encapsulation after testing, while the right is the load versus displacement curve of the bolt from each drop test. As can be seen, the vibration frequency of the curve is very consistent with the plough markings left in the polymer after pulling the upset though it, which suggests the yielding mechanism of the Yield-Lok bolt.

6 Conclusions

Seismic loading is considered in the support design of a 4 km long hanging conveyor belt tunnel in a seismically active area with 50 years of service life. The hanging support system is required to possess high yielding ability to prevent the conveyor belt system from falling to the ground during an extreme seismic event. The Yield-Lok bolt is selected as the hanging support system for the conveyor belt. The bolt performs consistently under static and dynamic loading conditions. It has high energy absorption capacity and is suitable for a service life of 50 years.

Acknowledgement

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