

A new dynamic test facility for support tendons

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The capability with which ground support systems can absorb energy arising from highly stressed, burst prone or high deformation mining environments is an increasingly key parameter for the design of a ground support system. It is critical for geotechnical practitioners to have access to sufficient information on the performance of ground support to facilitate informed decision-making whilst designing support standards for mines. Given the high strain rates imposed on support tendons during underground dynamic loading, the laboratory testing of tendons under similar loading rates is beneficial to better understand the behaviour of the support elements. Additionally, access to dynamic test facilities for manufacturers of support units improves the efficiency with which new support units can be developed and qualified for implementation underground.

A number of test methods have been investigated and utilised since initial in situ blasting methods were trialled nearly 50 years ago, these include laboratory-based and in situ underground testing of installed tendons. Different testing methods have provided for dynamic testing of individual support elements, i.e. tendon, faceplate and nut, or larger support systems incorporating a number of support elements acting together.

The laboratory test facilities most commonly used by industry for the dynamic testing of support tendons are in high demand with limited testing capacity which imposes a constraint on the rapid development of new rock support products.

Given the increasing need and benefit in better understanding and designing dynamic support elements, New Concept Mining built a new dynamic test machine, the Dynamic Impact Tester (DIT), at their research facility in Johannesburg, South Africa. Whilst it is accepted that laboratory-

based testing is not fully representative of rockbolt performance when subjected to dynamic loading underground, it is extremely valuable to have the ability to conduct a high number of tests with repeatable parameters to generate sufficient knowledge of the relative performance of different support systems.

The dynamic test machine is designed to test individual tendons (rockbolts and cables), including the faceplate and nut. In accordance with ASTM D7401-08 Standard Test Methods for Laboratory Determination of Rock Anchor Capacities by Pull and Drop Tests (ASTM, 2008), the machine utilises a falling weight impacting on the test sample to impart an energy impulse to the test sample.

Varying the mass and impact velocity of the weight, within the limitations shown in Table 1, allows for testing of different input energies at differing input velocities. This test envelope is illustrated in Figure 3.

A minimum test sample length of 1 m and a maximum sample length of 3.5 m allows for the testing of full size samples for the majority of rockbolt lengths used to support underground mines.

Testing on tendons can be conducted using one of two accepted test configurations. A continuous tube test imparts the impulse directly to the

faceplate of the test sample (Figure 4), whilst a split tube test imparts the impulse indirectly to the test sample by impacting on a strike plate attached to the steel embedment tube at the head of the bolt (Figure 5). A split between the head and toe lengths of the embedment tube simulates a discontinuity in the rock mass. The two different configurations simulate, to some degree, varying behaviour of a rock mass during a dynamic event.

Data interpretation and reporting

During testing, the DIT records a number of variables including displacement at the head and toe of the sample and the impact force applied to the strike plate by the falling weight. Data is collected at a sampling rate of 10 kHz with each data point time stamped to allow accurate correlation of different test parameters for analysis, no data filtering is

Table 1 Test parameter boundaries

Specification	Value
Maximum impulse	65 kJ
Maximum impact velocity	6.42 m/s
Maximum drop mass	3171 kg
Minimum drop mass	551 kg
Maximum drop height	2.1 m
Maximum sample length	3.5 m
Height of structure	8.2 m

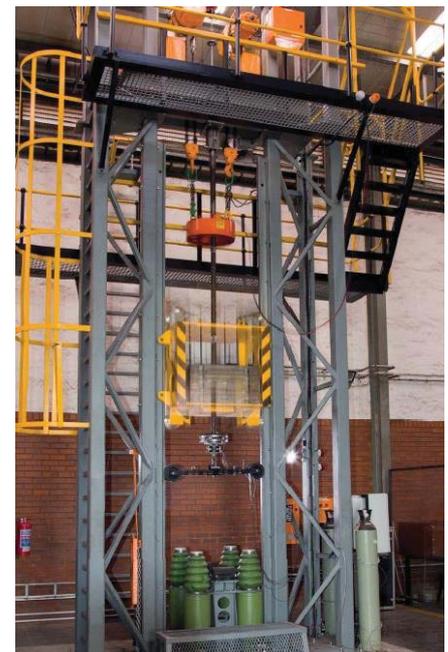


Figure 2 The DIT, as installed



Figure 1 Schematic of Dynamic Impact Tester (DIT)

Dynamic Impact Tester Energy Map

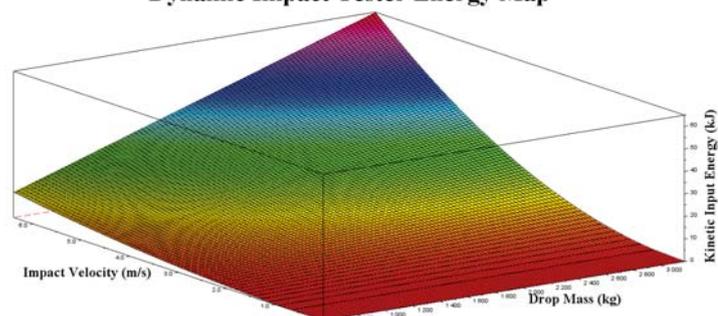


Figure 3 DIT test envelope

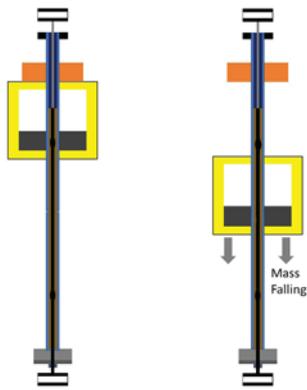


Figure 4 Continuous tube test

applied to the dataset by either hardware or software. A typical example of load and displacement data recorded during a test is shown in Figure 6.

The energy absorbed by the rockbolt during testing is calculated utilising the data captured to perform an energy balance calculation to account for energy losses arising from testing factors such as frictional and acoustic losses. The velocity with which the mass impacts the test sample is calculated theoretically, as per industry practise, but upgrades to the machine are in progress to allow for the accurate measurement of the weight's velocity during the test event. The calculation of the energy absorbed by the rockbolt is typically represented together with the applied load measured during the event (Figure 7).

In November 2017, Professor John Hadjigeorgiou of the University of Toronto reviewed the testing facilities of the DIT. Following a series of impact tests and analysis onsite, it was concluded that the facility, procedures and interpretation of results were consistent with international practice of similar rigs. A number of research opportunities using the DIT were also identified.

The frequency with which tests can be conducted on the DIT allows for an increased test rate for both single and multiple impact tests, as well the rapid processing of test results. Sample preparation comprises the bulk of the lead time required to complete testing. Subject to material availability, resin or friction anchored units require a minimum of 3 days preparation and grouted units require a minimum of 7 days due to curing of the grout. Prepared samples can be tested at a rate of 3 to 6 samples per day, depending on the test configuration and failure mode of the test samples.

The ability to conduct a large number of tests provides the opportunity to rapidly increase the knowledge base on the dynamic performance of support elements. Over a period of six months in 2017, the DIT performed 179 dynamic tests on a number of different tendon configurations. The quick turnaround time between tests is particularly noticeable when conducting

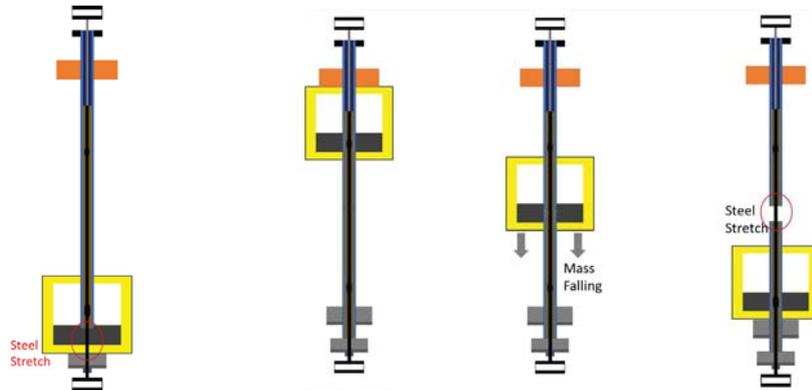


Figure 5 Split tube test

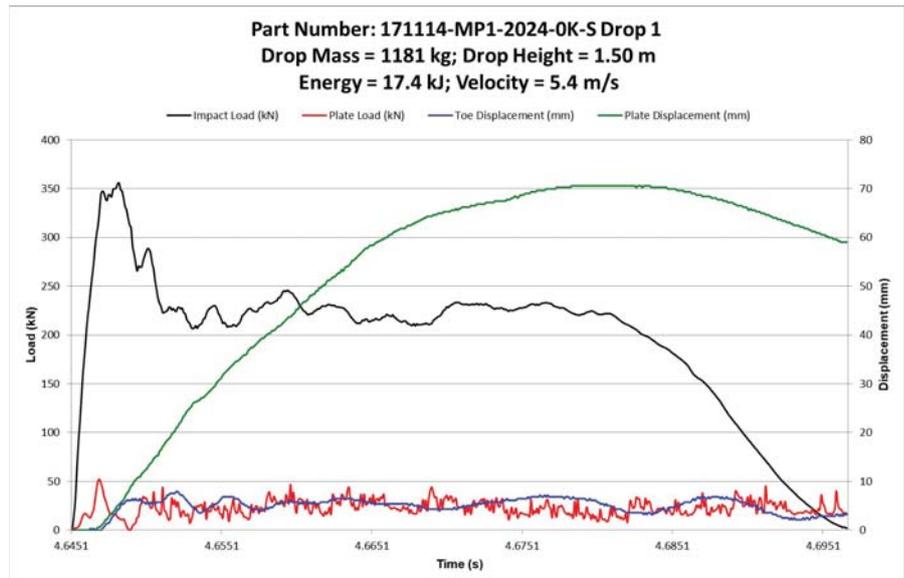


Figure 6 Typical load and displacement data from a single drop

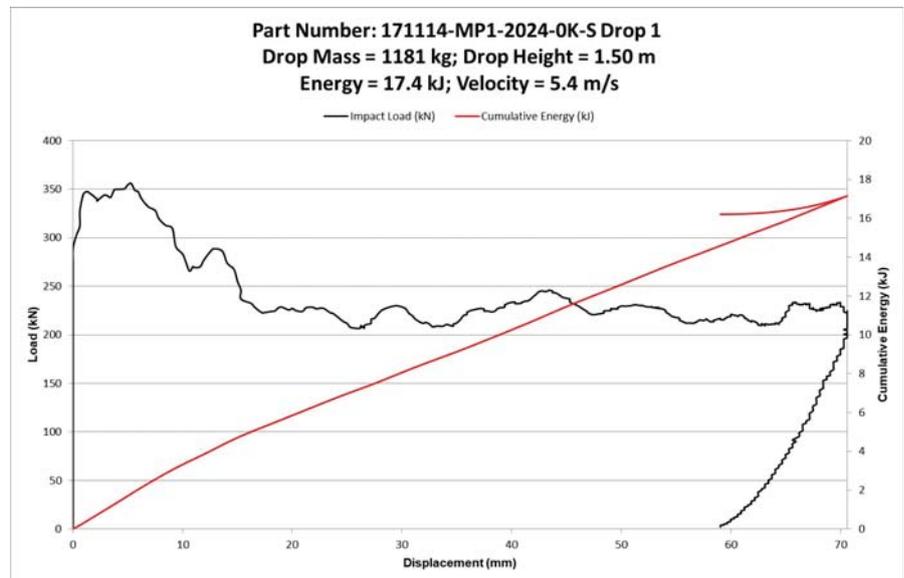


Figure 7 Typical load and cumulative energy absorption from single event

multiple impact tests (Figure 8).

The increase in test reports available for dynamic support units will provide geotechnical practitioners with greater confidence in the consistency with which support elements will behave under a set of loading conditions. Figure 9 plots the behaviour of four identical test samples, each subjected to five dynamic events

during testing. Comparison of each test sample's load deformation curve provides the insight needed on the reliability of the particular support element.

An added advantage of the DIT is the inclusion of a high definition camera that allows for the live streaming of tests globally over a secure online connection. This allows larger teams to witness the

dynamic testing of tendons without the expense or time required to travel to the test facility.

Path forward

A new test machine has been successfully built and commissioned for the dynamic testing of rockbolts and tendons between 1 and 3.5 m in length. With a testing capability between 8 and 65 kJ on a single event at a maximum impact velocity of 6.42 m/s, and equipped with state-of-the-art instrumentation, the DIT offers the geotechnical community the opportunity to gain a better understanding of the dynamic performance of support elements.

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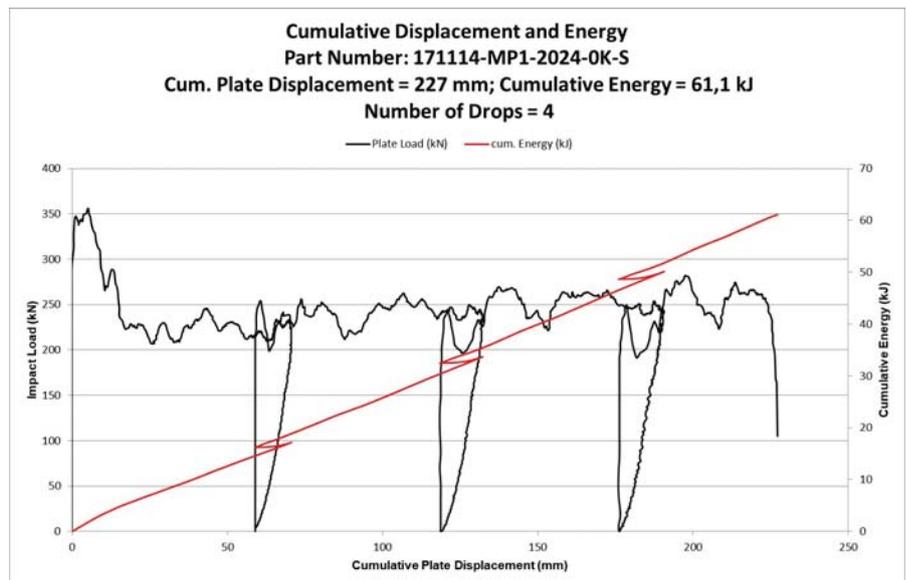


Figure 8 Typical load and cumulative energy absorption from multiple events

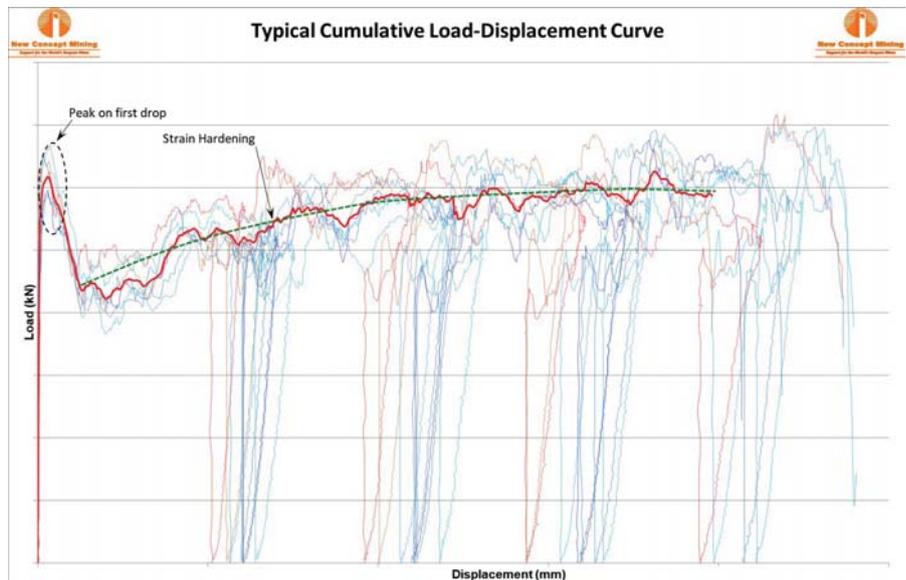


Figure 9 Multiple event testing on four samples

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