our future through science

The role of steel wire ropes in mine safety

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BACKGROUND

South Africa has a number of world-class mineral deposits, such as the gold mined in the Witwatersrand and the platinum, palladium and chrome mined at the Bushveld Complex. Like many other deposits, these mineral deposits are initially accessible from the surface and are exploited using surface mining techniques. However, as surface deposits are exhausted, mining must follow the mineralisation deeper underground.

Underground access is only possible through a series of vertical, or incline shafts and during its lifetime, an underground mine may sink many surface and sub-surface shafts to access the ore.

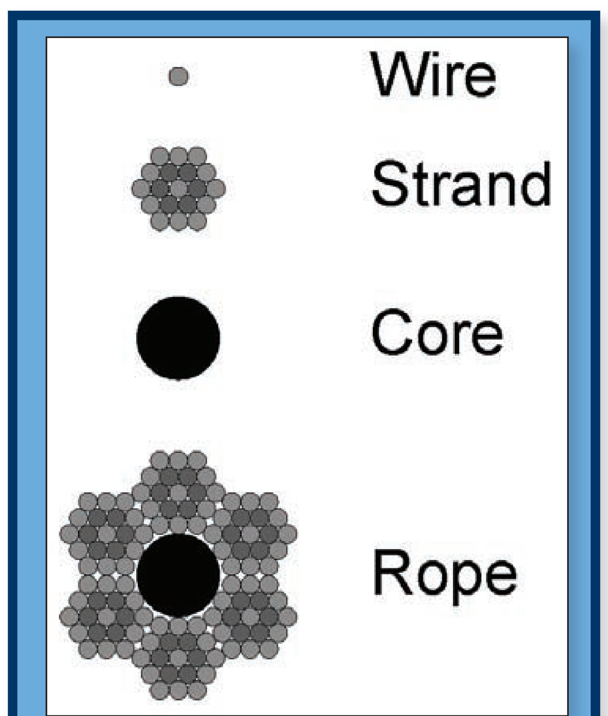
On paper a mine shaft can be almost any shape although common sense and cost dictate that it is either rectangular or circular. For strength, deep shafts in South Africa normally opt for a circular cross-section especially when traversing poor ground and going to great depth. On the surface we may choose any one of several routes between points A and B. However, this flexibility is not available in an underground mine, primarily due to the cost associated with sinking. A shaft system (two or more shafts) is the only access to and from underground and it is therefore critical that it is safe and functions optimally at all times.

A shaft is sub-divided into compartments, of which there are commonly 10 or 12 - depending on the shaft diameter. Of the compartments in this example, eight or nine will be equipped with conveyances, with a separate compartment carrying all services (electricity, water, etc).

FUNCTION OF STEEL WIRE ROPES

To date, the only method that has been devised to transport workers, equipment and rock in a shaft is some form of conveyance running in steel guides that stretch the length of the shaft from surface to the bottom. To maximise capacity, a conveyance may often have three decks and a carrying capacity of 150 (50 persons per deck) and travel at speeds of 15m per second.

The hoisting of broken ore to surface is normally conducted in one or more dedicated compartments. These compartments are equipped with skips (a special type of conveyance designed to convey rock) with capacities up to 20T.



Wire rope consists of several strands laid (or 'twisted') together like a helix. Each strand is made of metal wires laid together like a helix. Initially, wrought iron wires were used, but today steel is the main material used for wire ropes.

Construction of wire ropes

Steel wire ropes are currently the only practicable method of suspending and moving a conveyance between operating levels in the shaft and surface. A conveyance is suspended from one end of the steel wire rope, with the other end attached to the winding engine drum. As mines have gone deeper (today the deepest mine in South Africa, and the world, is operating 4 km below surface) steel wire rope technology must continue to perform with absolute safety.

Steel wire ropes from the CSIR's engineering testing laboratories

IMPORTANCE OF STEEL WIRE ROPES IN MINE SAFETY

Today there are an estimated 2 300 steel wire ropes installed in roughly 200 underground mines in South Africa. These mines employ more that 280 000 workers underground and hoist several millions of tonnes of rock to the surface every month.

LEGISLATION

In 1904, a winding rope broke in a shaft at the Robinson Deep mine in Johannesburg causing the deaths of 46 miners. In the same year, legislation was passed making it mandatory for mines to cut samples from the 'front end' of the winding rope (the section attached to the conveyance) at six month intervals, which were to be sent to the Government Mechanical Laboratory for destructive tensile testing. This practice continues to this day.

The CSIR's engineering testing unit in Cottesloe, Johannesburg hosts one of two test laboratories in South Africa that is accredited by the Department of Minerals and Energy (DME) to conduct these tests.

CSIR staff inserting a rope specimen between the cross-heads of the 15MN tensile test machine

THE HISTORY OF THE CSIR'S ENGINEERING TESTING UNIT

The engineering testing laboratories of the CSIR were built in 1935, and equipped with a 500T tensile and a 1 000T compression test machine.

Over time, wire rope technology evolved to deliver larger diameter ropes with higher breaking forces, able to cater for increasing mining depths and heavier payloads. As a result, rope technology and industry needs outgrew the capacity of the 500T machine and it was replaced by the 1 000T (10MN) machine in 1973. Further advances in rope technology eventually resulted in this machine being replaced by a 15MN, commissioned in 1989 and still in use today.

SETTING THE BENCHMARK

During the 1990's a working group was set up that drew engineers from the mining industry, SA Bureau of Standards, the Department of Minerals and Energy (DME) and the CSIR to investigate criteria that could be used to define when a steel wire rope is no longer fit-for-purpose.

The principal output of the working group was a list of rope discard criteria that today form the benchmark for every wire rope test. These criteria are incorporated into a code of practice for steel wire ropes, SABS 0293:1996.

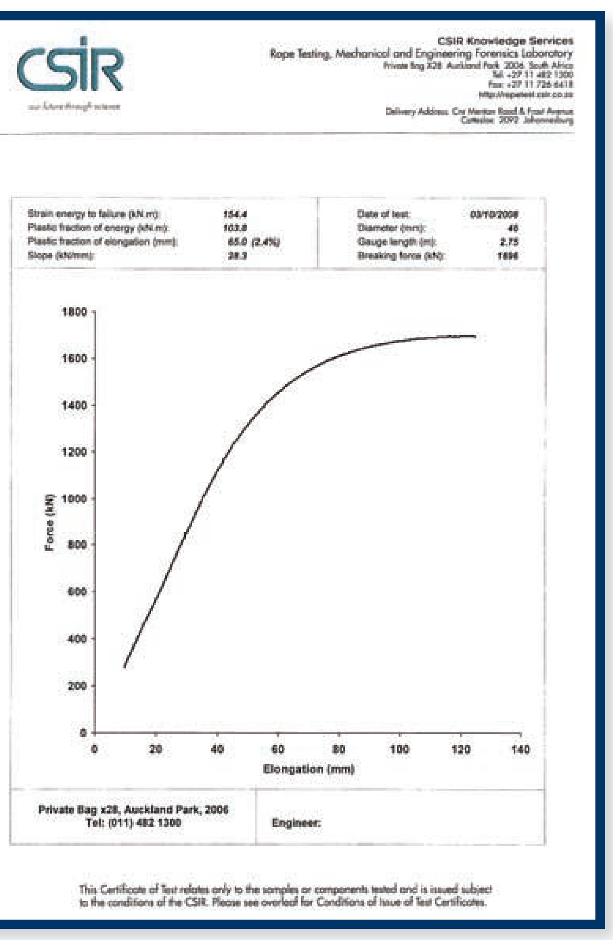
Examples of discard criteria are:
Breaking force: 10% or greater reduction in the 'new rope breaking force'
Plastic fraction of elongation: 0,5% or less.

All critical information relating to the rope's condition is recorded during a test. A subsequent visual examination of the rope will assess the rope's condition, including the amount of corrosion, the type of wire failure (ductile, cuppy, shear, etc.) and degree of lubrication. Any other pertinent observations, for example the degree of 'nicking' will also be recorded. This information is captured in the bottom section on the first page of the test certificate.

Rope and data traceability is maintained throughout, and the certificate also provides the rope's 'history' from date of manufacture (coil no.), date of installation, winding plant permit number, as well as the new rope breaking force, and the breaking force determined at the previous test.

Should a rope fail to meet either of the two key criteria, namely the breaking force and plastic fraction of elongation, the mine is informed and depending on the specific circumstances, a second specimen may be sent for test, or the rope is removed from service.

This graph illustrates a rope in good condition, and the typical 'bow' shape of the graph is clearly visible. The upper section of the graph shows that the plastic fraction of elongation represents substantially more than 0,5% of the total elongation of the rope before fracture. Further information on the rope including the breaking force can be seen above the graph.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Strain energy to failure (kN.m):	154.4	Date of test:	03/10/2006
Plastic fraction of energy (kN.m):	103.8	Diameter (mm):	40
Plastic fraction of elongation (mm):	65.0 (2.4%)	Gauge length (m):	2.75
Slope (kN/mm):	28.7	Breaking force (kN):	1696

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This Certificate of Test relates only to the samples or components tested and is issued subject to the conditions of the CSIR. Please see overleaf for Conditions of Issue of Test Certificates.

Graph illustrating a rope in good condition

There are more than 280 000 underground mineworkers in South Africa, and their lives depend on the steel wire ropes that transport them up and down mine shafts. The CSIR is one of only two local, accredited testing facilities that conduct tests to ensure that these ropes comply with safety standards.

THE CSIR, LEADERS IN STEEL WIRE ROPE TESTING TECHNOLOGY

The capacity of the tensile test facility at the CSIR in Cottesloe is almost certainly unique in the southern hemisphere, and definitely in Africa. The facility therefore receives ropes for testing from a number of other countries in southern Africa including Tanzania, Botswana and Namibia.

The CSIR's engineering test laboratory will accept steel wire ropes up to 160mm in diameter and to date, the greatest force exerted on a rope under test was slightly over 1 500 tonnes. Ropes of these dimensions and capacities have application in the manufacturing of lifting slings, the marine industry and oil well platforms. Several applications are outside South Africa.

IN CONCLUSION

The role of steel wire ropes in mine safety and their contribution to productivity cannot be overstated, although in future this role may be challenged by new developments using synthetic materials.