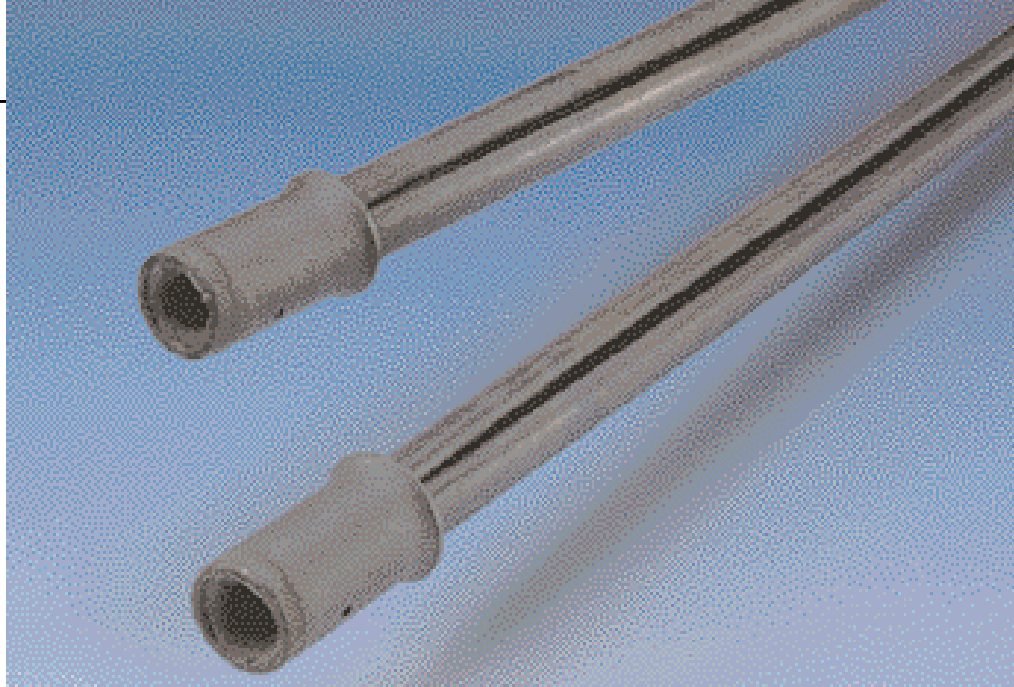
TECHNICALLY speaking



Swellex goes manganese

A quantum leap in rock reinforcement

Atlas Copco's Swellex rock bolts have a long and successful history based on two simple advantages for the customer: safety and productivity. The latest range of frictional bolts, called Manganese Line, will dramatically increase performance – thanks to a new steel composition and an innovative heat treatment.

Swellex rockbolts are watertight, double-folded, high-quality steel tubes which are expanded by a high-pressure water pump throughout a pre-drilled hole.

The expansion of the tube generates both contact friction and mechanical interlock between the steel and surrounding rock, giving immediate and full-column rock reinforcement in a simple and rapid way.

In planning a new generation of Swellex bolts, Atlas Copco identified the opportunity to further increase the productivity, performance and reliability of Swellex pumps – and to re-engineer the bolt itself so that a quantum leap forward in safety and performance could be achieved.

Loading capacity normally defines a class of rock bolt. For example, Standard Swellex is a 100 kN bolt, while Super Swellex is in the 190 kN category. But other parameters can influence the final performance of a rock bolt and especially its contribution to safety. So our R&D specialists targeted a new generation of Swellex which would be better suited to the rock mechanical requirements.

A new tool

Experience in mining and tunnelling operations has shown that elongation is a very important parameter in judging the performance of a bolt. Deep mines, strain concentration areas, uneven load, progressive deformation and squeezing ground are all cases in which a bolt with a superior capacity to follow the rock deformation can play an important role in balancing and re-adjusting the strain field towards stability. But elongation without tensile strength is simply out of the question.

Atlas Copco needed a new tool to measure the total performance of rock bolts – a new parameter able to combine capacity and elongation. The classical load/deformation graph can also be considered as an equation of loading capacity in the function of elongation: Tensile Load = function (displacement).

Tensile Load vector has a physical dimension as a force [F] and displacement vector has a dimension as a length [s]. The area described beneath the curve has therefore, a physical dimension of Work [W]. In reality, displacement is normally expressed in percent, so we only get an index [Wi]. We have defined the integral of load in function of deformation as "Work Index of the bolt."

$$W_i = \int_0^{s_1} f(s)*ds$$

Where W_i is the Work Index, s_1 is the material failure limit, f(s) is the tension load as a function of displacement and ds is the displacement increment. This index gives a good picture of the total energy absorbed by the bolt before breaking down or losing its function.

In search of excellence

The Swellex range is based on several hole sizes. Standard Swellex is used in combination with holes from 32-39 mm in diameter while both Super and Midi Swellex work in the 43-52 mm range.

A possible solution to increase the Working Index was to increase the geometrical feature of the bolts.

With Swellex being a commercial success worldwide, it was considered a difficult task to modify its well accepted and fit-to-application dimensions. It seemed more logical to work on material properties and production methods.

The steel used for the production of today's Swellex is already a special type with few impurities. Our well-established co-operation with a leading steel supplier and with a pipe mill has allowed a special technical specification to be developed for materials that is tailor-made for the

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purpose. A series of alloys and high tensile steels were first considered, but only a very limited number of options can handle the severe requirement of Swellex rock bolts (radial deformation during expansion, weldability to assure perfect water-tight contacts at the bushings).

But the final decision was to use a higher quality steel with a substantial content of manganese.

Produced in a cold forming mill, the steel reaches a very high tensile strength and high loading capacity, but unsatisfactory elongation. A post production heat treatment somewhat reduces the peak resistance, but gives extraordinary elongation properties to the Swellex profile.

Improved behaviour

Figure 1 compares typical load/deformation curves for today's Super Swellex and the new **Swellex Mn24**. In particular, the regular Swellex steel profile shows a classical behaviour for carbon steel; beyond the yielding point (200 kN), the profile accepts a large amount of deformation, but with slightly lower strength. When a 20% elongation is reached, the profile breaks down.

The new, high-strength and fully annealed **Manganese Line** now offers a higher loading capacity and, at the same time, enhanced elongation. Figure 1 shows that, beyond yielding point, the manganese steel increases the load capacity due to the hardening process.

The curve continues to point upwards until a 10% elongation is achieved; a long horizontal segment goes above the 30% level before the profile breaks up. This extraordinary behaviour gives the capacity to absorb a substantially higher quantity of energy, as indicated in the so-called Work Index, incremented by 90%.

Total reliability

The heat treatment used during the production of the new Swellex Manganese further improves repeatability of the performance obtainable by the bolts. A large number of pull tests, representative for millions of rock bolts, show a very little variation in the results.

Now, more than ever before, engineers, miners, rock-mechanics and consultants can rely on safe and quality controlled rock bolts – from manufacturing to installation. M&C 1•01

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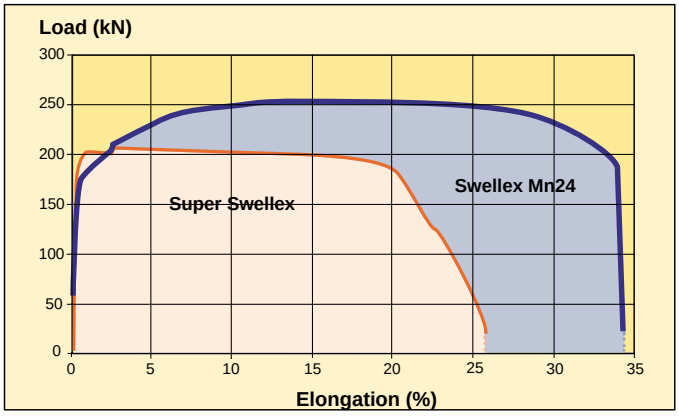

Figure 1. The excellent performance shown by the Super Swellex rock bolt (red line) is further improved by Swellex Mn24 (blue line), the corresponding bolt in the new Manganese Line. This load/displacement diagram shows a higher value for both loading capacity and elongation. The Working Index for Swellex Mn 24 (the area defined by the curve) is about twice that delivered by today's Super Swellex bolts.

Rock Bolt type	Ultimate Load		Elongation (A5)		Work Index	
	kN	Increase	%	Increase	kN x %	Increase
Standard Swellex	100		20		2000	
Swellex Mn12	120	+20%	30	+50%	3600	+80%
Mini Swellex	120		20		2400	
Swellex Mn16	160	+33%	30	+50%	4800	+100%
Super Swellex	200		20		4000	
Swellex Mn24	240	+25%	30	+50%	7200	+80%

Figure 2: After a series of experiments, a heat-treated Manganese steel in the family of EN 10 025-S355JR was chosen. This table shows the results of the design efforts. It refers to tensile tests of the profile after expansion to simulate real conditions. The numbers are typical values. Work Index is a parameter used to express the combination of the two major parameters (load capacity and elongation) which together define the performance of a rock bolt.