# Understanding the physics of cable

## Crane users looking for longer lasting cables need to understand that a cable's tensile strength is limited by the physical properties of its materials

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In the cable business, manufacturers are continuously looking for new technologies and production methods to give them an advantage. Recently, however, Prysmian has seen several claims from cable manufactures and system integrators purporting to offer performance that exceeds well-proven principles and Prysmian believes this is causing confusion. Technology does advance, and sometimes established principles and standards need to be updated, but before this can take place new concepts need to be proven by serious tests, scientific investigations, publications, and finally field tests and experience. This article will give some basic information about cable design and the factors influencing cable performance that are intended to reduce confusion and help end-users properly consider marketing claims.

The design aspects that make a good reeling cable include: conductors, insulation, core arrangement, inner sheath and interstice filters, outer sheath and additional stabilizing elements, support elements, anti-torsion braids and electrical screens. Every aspect is important but one of the most frequently discussed and important to end-users is the tensile load and flexibility of cable.

### Know the limits

All cable manufacturers have to work with the physical properties of copper, and it is important to understand how much tension copper is able to carry as the copper conductor always takes the tensile load, unless a support element is used. Copper properties can be split into two areas: elastic and plastic. Within the elastic range, copper behaves like a spring and fully relaxes when the load is released. Its plastic characteristic is different: copper gets permanently elongated until it breaks.

The elastic range of copper permits a maximum elongation of 0.2 percent (as shown in Figure 1). The load has to stay within that elastic area under all circumstances, otherwise permanent damage results. A projection of the 0.2 percent strain value to the tensile axis shows a corresponding tension of 150N/mm² as a maximum limit to the plastic area.

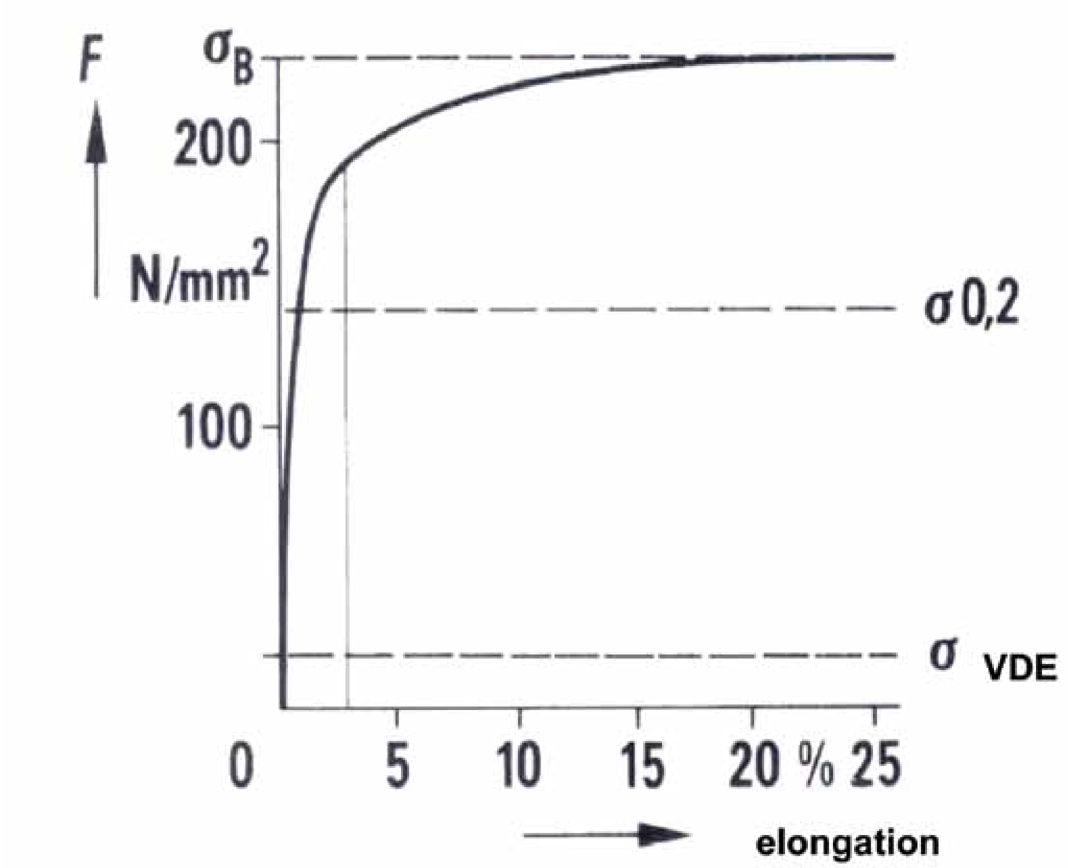


Figure 1. Stress-strain diagram of copper.

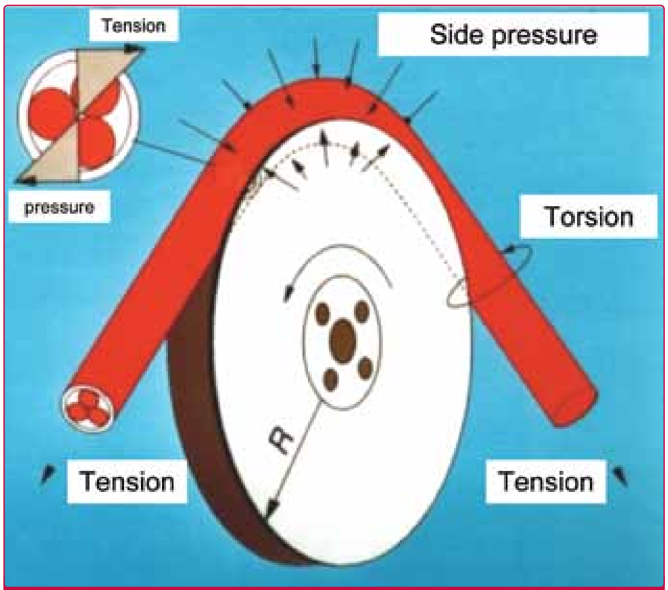

Figure 2.

In the German standard DIN VDE 0298, the limit for pure tension is set much lower at 15N/mm (see dashed line named as σ-VDE). This seems very conservative and data sheets of several cable makers show that some allow more tension, for example 30N/mm². This would seem acceptable as there is still room left within the elastic area. However, pure tension is not the only load on the copper.

## Understanding tensile load

Figure 2 shows the stresses on a cable when it runs over a single roller. Besides the tensile load, cables are subject to bending stresses, torsion and side pressure. The pure tensile load is the primary stress, but if we analyze bending and torsion in more detail we discover the resulting forces end up as an additional (secondary) portion of tensile load.

The outcome is that we cannot use the entire elastic area only for pure tension; some 'room' must be left to cover secondary impacts. It is difficult to quantify the value of secondary impacts as there are many influencing factors, for example roller diameter, bending radius, and so on.

The number of load cycles and the load intensity also have to be considered. To meet the long lifetime expectation, the ratio of load cycles and load intensity has to be inversely proportional. In other words a high number of load cycles requires low load intensity, and a lower number of load cycles allows higher load intensity. Where the expected number of load cycles is high and load intensity is high, cable lifetime will be reduced as a result.

This consideration is based on physics – if the pure tensile load is set too high, a reduced lifetime is the outcome. Investigations have shown that 40N/mm² (pure tension) is too high and causes a significant drop in the cycle lifetime.

## How to increase tensile load?

If the required tensile load cannot be managed with the copper conductors, special measures have to be taken. The addition of support elements increases the tensile load of the cable while protecting the copper conductor. The challenge for the cable manufacturer is where and how to strengthen the cable and there are different designs available.

The material used in the support element is an important consideration and it must be tension resistant at low elongation. The most ideal space for the support element is the centre of the

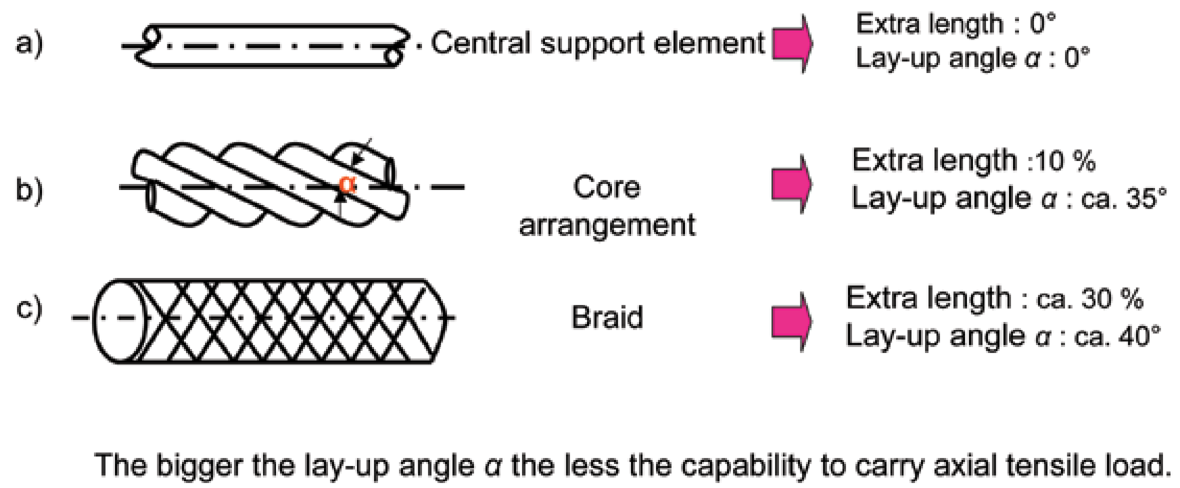


Figure 3. Support elements.

cable. This is because the center line provides the opportunity to build in the support element in a 'stretched' way, without any extra length reacting immediately on tensile load (Figure 3a). An alternative is using a wound construction around a central support element (Figure 3b). The support element is activated through the compression forces on the wound elements under axial load, allowing it to carry the tension. This technology has been tested and proven over many years in thousands of applications.

Support elements designed as a braid are also available, but they have several disadvantages. Because of the braid angle and extra length of braided material (Figure 3c) a reasonable axial elongation is required until the compression force is big enough to carry tensile load. Until that point is reached the tensile load is on the copper conductor and it might already be damaged before the braid becomes active.

Other disadvantages of a braided support are cable stiffness, which is not beneficial in 'flexible' applications and impacts on other crane components, such as the reeling system. Comprehensive investigations have also shown that braids tend to break in the early stages of bending stress, rendering them ineffective as a support element. Prysmian's field experience in crane and mining applications is that braided support elements have not performed well.

## ABOUT THE COMPANY

**Prysmian** is one of the world's leading players in high-tech energy and telecom cables and systems, with a strong position in high value-added market segments. It develops, designs, produces, supplies and installs a wide range of products and services in the two sectors covered by its two divisions:

- Energy Cables & Systems for underground and submarine power transmission and distribution, both for industrial applications and for residential and commercial buildings;
- Telecom Cables & Systems for video, data and voice transmission.

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