# Ropes and rope constructions

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The six articles in a series entitled "Steel Wire Ropes for Traction Lifts" delve into questions of concern to rope makers and users in recent years. These articles are intended to help answer questions frequently asked and to support troubleshooting whenever a combination of elevator and suspension ropes behaves in an unexpected fashion. Many of the answers stem from research projects or from work carried out with lift owners or operators when searching for the cause of a problem. At this juncture the authors would like to thank all those involved for their frankness and openness.

The present article, the second in the series, deals primarily with rope designs and the technical regulations that affect ropes when used in elevators.

**The simplest elevator rope is obtained by laying 6 strands, for example using the Warrington construction, around a fibre core (Fig. 15). Up until the nineteen fifties, this was practically the only kind of rope used. Since this time, the demands imposed on traction drive elevators in terms of speed, shaft height and traffic flow as well as expectations of ride quality have increased tremendously.**

The changing ratio of elevator car weight to payload is giving rise in some cases to dimensions which are unfavourable, for example in terms of traction capability. Today, the 8-strand rope with natural fibre core has made great inroads in the international arena, and may be considered the most frequently used elevator rope today (Fig. 16 and Fig. 17).

## What are the rules, regulations and requirements appertaining to ropes in traction drive elevators?

In order to prolong the service life of a rope, the contact pressure between the rope and groove must be restricted. This results in a minimum number of ropes and also minimum rope diameters. The calculated contact pressure is dependent upon the rope surface and independent of the breaking forces, and consequently also the rope cross-section area. TRA 003 [6]/EN 81-1/1986 [7] take into account a simplified form of pressure calculation. This is no longer in evidence in EN 81-1/1998, and is intended to be addressed by a special calculation of the rope safety factor according to Annex N. However, the factor of contact pressure should always be borne in mind. High minimum safety factors (ratio of minimum breaking force to operating load) of 12 (USA and Japan 10) require only a minimal metallic cross-section in the rope. But precisely because of the service life-diminishing effect of pressure, the rope diameter as a factor must not be left out of account. This is why the 8-strand rope with fibre core, which adequately complies with the calculated requirements (relatively low breaking force coupled with relatively high rope diameter) is in such widespread use. Further reaching requirements:

- Small permanent elongation (fewer rope shortening processes),
- Small elastic elongation (car suspension, ride comfort),
- Small diameter reduction in operation (service life),
- Longer rope service life due the use of more and thinner wires,
- The rope should be more rounded than an 8-strand rope, the actual contact pressure is reduced by the existence of more contact points of the rope on the side of the groove and
- The rope should remain round in operation and should adjust, in particular in hardened U-grooves, with a larger undercut.

This long list of requirements is complied with in the case of full steel ropes, with the number of outer strands being additionally increased to 9. Fig. 9 illustrates examples of full steel ropes. Fig. 19 illustrates a proven elevator rope construction with steel wire core. Following the highly successful use of this type of elevator rope with steel wire core in a number of complex and demanding building projects, they have been included in the international standards.

It should be emphasized that Germany has for a long time been the sole pioneer in the manufacture and application of elevator ropes with steel wire core. Still

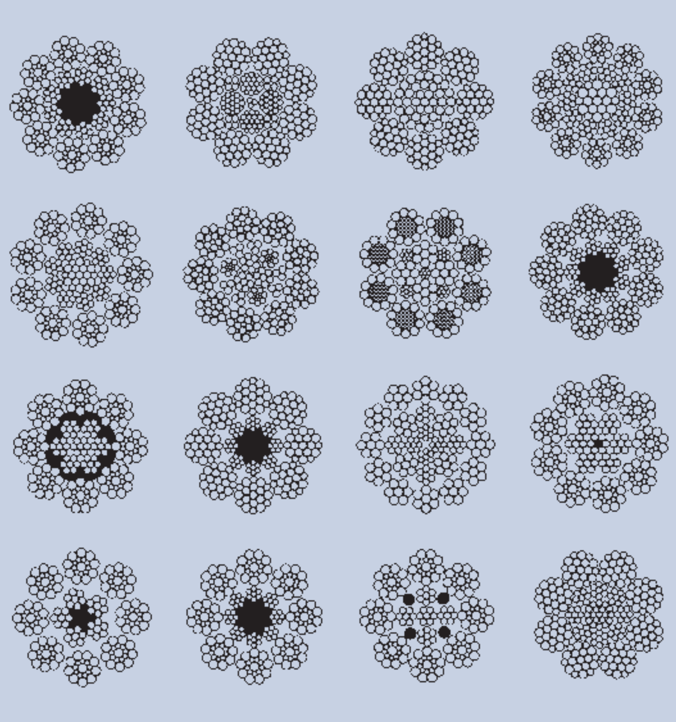

*Fig 9: Overview of full steel elevator rope constructions*

today, for instance, some elevator manufacturers abroad erroneously assume that this type of rope is prohibited in their country, simply because the only elevator standard applicable in that country is one for ropes with fibre core. When using ropes with a steel wire core, it should be made clear that the benefits including long service life and reduced rope elongation are brought to bear if the installation is designed for an 8 x 19 + fibre core construction and is then operated using the same number of ropes of the same thickness with steel wire core. However, if the increased minimum breakage force of these ropes is used as a reason to reduce the number of ropes or the rope diameter, then this benefit is at least partially "balanced out".

Rotation-resistant rope constructions (Fig. 10) should not be used in traction drive elevators, as these entail crossover of the outer and inner strand layers and high contact pressure levels. This leads to the danger of unnoticed inner rope damage.

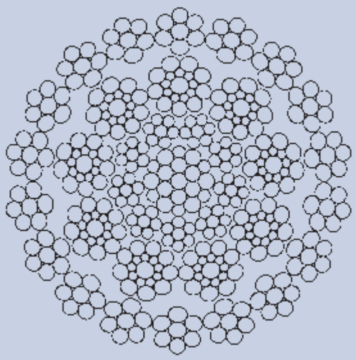

*Fig. 10: Rotation-resistant rope constructions (example)*

## Why this degree of diversity in elevator rope constructions?

Does the single ideal elevator rope exist, or to take this possibility even further, could there actually be one rope to cover all conceivable applications? A rope used in traction drive elevators is exposed to a complete collective of stress factors comprising flexure, tension and compression but also abrasion between the wires and between the rope and sheave due to the unavoidable effect of slip. A high level of flexural stress calls for the use of a large number of thin wires in the outer strand layers. Under extreme wear conditions, thick outer wires would be preferable, in other words the rope and strand construction must be selected depending on the predominant source of stress. If exposed to high levels of flexural stress, preference would be given to a Warrington rather than a Seale rope. Added criteria when it comes to selecting the right rope, however, include special country and manufacturer-specific factors and traditions.

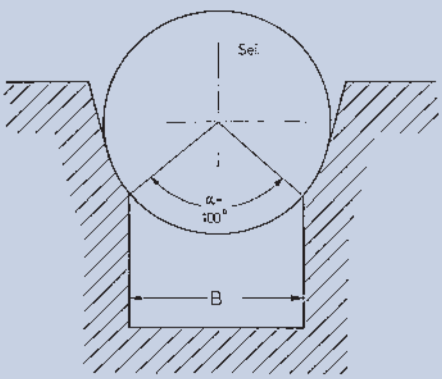


*Fig. 11: Rope and traction sheave, schematic view*

Rope selection is additionally influenced by the restrictions in terms of diameter for certain types of rope construction. Due to the extremely thin filler wires, 8 x 25 filler construction ropes (a rope with an extremely good fatigue bending life) is not produced with diameters of below 10 mm. A 6 x 19 Seale construction cannot be produced over 16 mm because of the thick outer wires which would result in excessive rope rigidity.

This goes some way towards explaining the wide diversity of rope constructions in existence. Added to this is also wide variation in traction drive elevators themselves. This diversity means that a single rope construction can never be sufficient to achieve optimum behaviour. The bandwidth of different elevators produced ranges from traction drive elevators with small and large shaft heights, roped hydraulic elevators and dumb waiters, taking in widely differing car suspensions and counterweights and so on. Another factor to bear in mind are also the tensioned balance ropes in installations from mean nominal speeds and the ropes used in overspeed controllers. In brief: it is impossible to address all the different application requirements, cost and benefit expectations with just a single rope construction. The use of high-performance ropes for a rarely used, slow-moving elevator can be eliminated if only for reasons of cost. Conversely, simple rope constructions are out of place in high-rise installations. In addition, all the rope constructions illustrated in Fig. 9 are special ropes which are not available from all manufacturers across the entire bandwidth. It is also essential to bear in mind in this debate that differential force brought about as a result of the different masses of the elevator car and counterweight has to be transmitted through friction between the rope and sheave. This calls for verification of what is known as the traction capability, which falls back on the model of the ideal round rope illustrated in Fig. 11. This procedure has proven successful and is not up for debate. However, the traction capability only constitutes one side of the coin. The actual installation conditions of the rope in the groove naturally play a major influencing role in determining the service life of the rope. This is impressively demonstrated by the example of a full steel rope with 6, 8 and 9 outer strands in undercut U-grooves with an extreme undercut angle of $\phi$ = 105° (Fig. 12 to Fig. 14). The right-hand illustration shows the rope with a rotated cross-section relative to the left-hand illustration, but with a fixed rope centre point. In most cases, a large number of strands and a dimensionally stable full steel rope is a suitable construction in most cases.

*Fig. 12: 6-strand rope in 105° U-groove*

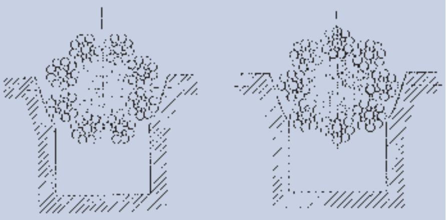

*Fig. 13: 8-strand rope in 105° U-groove*

*Fig. 14: 9-strand rope in 105° U-groove*

## Which ropes are suitable for which installations?

If you got an inquiry we offer you the annex to this article provides a simple aid for the selection of suspension ropes, tensioned balance ropes and governor ropes depending on the installation. It also explains which aspects resulted in the assignment of rope to elevator installation.

## What is required of suspension ropes for traction drive elevators?

The requirements imposed on ropes used in traction drive elevators are contradictory and in some cases even appear to be in competition. The requirements in summary:

- The smallest possible degree of rope wear (thick wires, high wire tensile strength),
- A long rope life when running over sheaves (thin wires),
- Careful treatment of the sheave (low wire tensile strength),
- The highest possible breaking force (fewer or thinner ropes, high wire tensile strength),
- Low rope elongation due to rope shortening processes and ride comfort expectations (high metallic cross-section and top-quality fibre core) and
- A low price (steel and good core material cost money).

These requirements can clearly not all be fulfilled at once. Comprise is called for, whereby it should be noted at this point that it is the rope elongation factor which increasingly determines the choice of rope with increasing shaft height.

**When is a 6-strand rope with fibre core used?**

Fig. 15 illustrates an example of this type of rope in the form of a 6 x 19 Warrington with fibre core. The benefits and fields of application are outlined in the following.

*Benefits:*

- A larger metallic cross-section, i.e. high breakage force relative to the rope diameter,
- Relatively low permanent and elastic elongation
- Favourable price per metre.

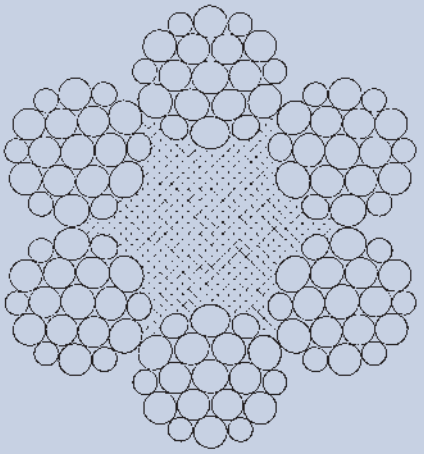

*Fig. 15: 6 x 19 W + NFC*

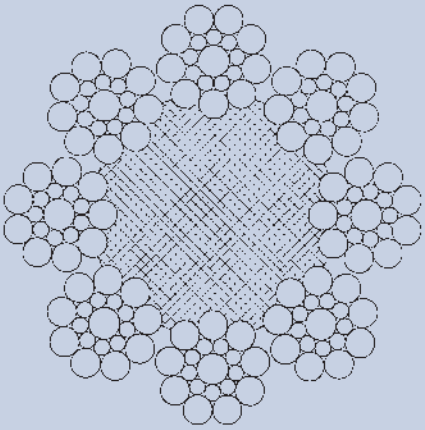

*Fig. 16: 8 x 19 S + NFC*

*Field of application:*

Slow travelling freight elevators and low-duty passenger elevators.

The use of this type of rope should be reconsidered for U-grooves with large undercuts or V-grooves.

**When is an 8-strand rope with fibre core used?**

Fig. 16 shows an example of this type of rope in the form of an 8 x 19 Seale with fibre core. The benefits and fields of application are outlined in the following.

*Benefits:*

- 8-strand ropes are rounder than their 6-strand counterparts, so creating more points of contact between rope and groove, and consequently ensuring more favourable contact pressure conditions,
- A slightly more easily deformable cross-section, i.e. the rope adjusts more easily to slightly worn grooves,
- 8-strand ropes have thinner wires than 6-strand ropes of the same construction, i.e. the rope is less rigid and offers better fatigue bending characteristics,
- A medium price per metre.

*Field of application:*

The 8 x 19 Seale construction with natural fibre core (Fig. 16) is internationally the most frequently used elevator rope. However, the 8 x 19 Warrington rope construction with natural fibre core (Fig. 17) also has a wide following due to its superior fatigue bending characteristics. It should be noted that the rope quality depends heavily upon the quality of the fibres used to produce the fibre core.

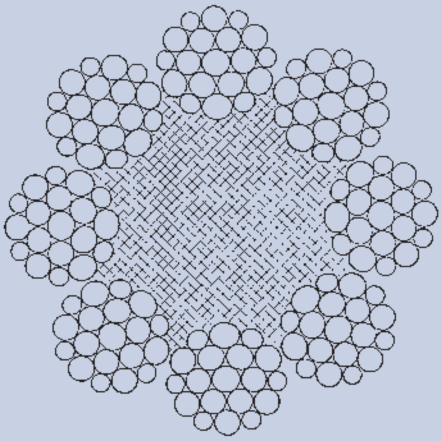

*Fig. 17: 8 x 19 W + NFC*


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