Steel Wire Ropes for Traction Elevators: Part Two

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Learning Objectives

After reading this article, you should:

- ◆ Have realized that the simplest elevator rope is obtained by laying six strands.
- ◆ Understand that the eight-strand rope with a natural fiber core can be considered the most frequently used elevator rope today.
- ◆ Have learned that depending on the intended application, two different core types are used in elevator ropes: fiber cores made of natural or synthetic fibers, and steel-wire cores.
- ◆ Have realized that the most commonly used suspension rope diameters are 6-24 mm.
- ◆ Have understood that the development of small rope diameters is being driven by the trend toward machine-room-less (MRL) elevators with small, fast-running drive machines and the move to reduce drive torque levels.
- ◆ Have realized that a distinction is made between detachable and permanent rope terminations.

Ropes and Rope Constructions

The simplest elevator rope is obtained by laying six strands – for example, using Warrington construction around a fiber core (Figure 15). Until the 1950s, this was practically the only kind of rope used. Since then, the demands imposed on traction-drive elevators in terms of speed, shaft height, traffic flow, and expectations of ride quality have increased tremendously. The changing ratio of elevator car weight to payload has given rise, in some cases, to unfavorable calculations in terms of such as traction capability. Today, the eight-strand rope with a natural fiber core has made great inroads in the international arena and can be considered the most frequently used elevator rope today (Figures 16 and 17).

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 rope diameters. The calculated contact pressure is dependent upon the rope surface and independent of the breaking forces and, consequently, the rope cross-section area. TRA 003[6] and 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 (U.S. and Japan 10) require only a minimal metallic cross-section in the rope. But precisely because of the adverse effects of pressure reducing the service life, the rope diameter as a factor must be taken into account. This is why the eight-strand rope with fiber core, which adequately complies with the calculated requirements (relatively low breaking force coupled with relatively high rope diameter) is in such widespread use.

Further considerations to improve the performance of ropes are:

- ◆ Less permanent elongation (fewer rope shortening processes)

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Value: 1 contact hour (0.1 CEU)

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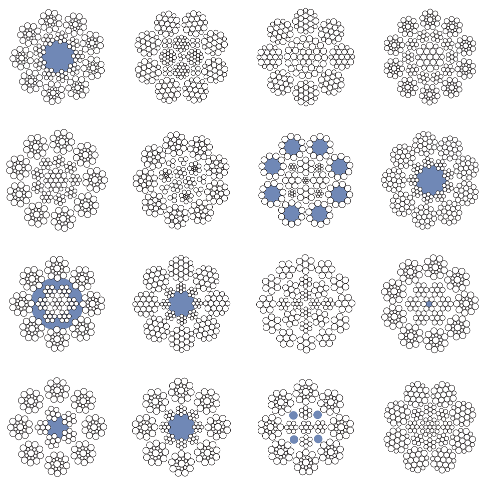

Figure 9: Overview of full-steel elevator rope constructions

- Less elastic elongation (car suspension, ride comfort and floor leveling accuracy)
- Less diameter reduction in operation (service life)
- Longer rope service life due the use of thinner wires in greater quantities
- The rope should be more rounded than an eight-strand rope. The actual contact pressure is reduced by the existence of more contact points between the rope and the side of the groove.
- The rope should remain round in operation and not adjust it shape – in particular, in hardened U-grooves, with a larger undercut.

This long list of requirements can be complied with use of full-steel ropes, with the number of outer strands being additionally increased to nine. Figure 9 illustrates examples of full-steel ropes. Figure 19 illustrates a proven elevator rope construction with steel-wire core. Following the highly successful use of this type of elevator rope in a number of complex and demanding building projects, it has been included in current international standards.

Germany was for many years the sole pioneer in the manufacture and application of elevator ropes with a steel wire core. Its benefits and use have since been adopted by other countries. Even today, some elevator manufacturers wrongly assume that this type of rope is prohibited in their countries simply because the only elevator standard applicable in that country is one for ropes with fiber cores. When using ropes with a steel-wire core, it should be made clear that the enhanced benefits of longer service life and reduced rope elongation can be considered an alternative for an installation being designed with a standard 8-X-19 fiber-core construction, and it can be operated using the same number of ropes of the same thickness as a steel-wire core. However, if the increased minimum breaking force of these ropes is used as a reason to reduce the number of ropes or the rope diameter, a small part of their benefit will be "consumed."

Rotation-resistant rope constructions (Figure 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.

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 collection of stress factors comprising flexure, tension, compression, and 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.

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) are not produced in diameters less than 10 mm. A rope with 6 X 19 Seale construction cannot be produced over 16 mm because the thick outer wires would result in excessive rope rigidity.

This goes some way toward explaining the wide diversity of rope constructions in existence. Added to this is the wide variation in traction-drive elevators. This diversity means that a single rope construction would never be sufficient to achieve optimum behavior. The bandwidth of different elevators produced ranges from

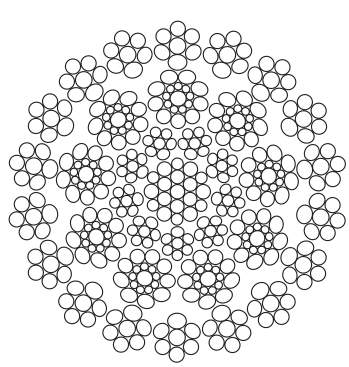

Figure 10: Rotation-resistant rope construction

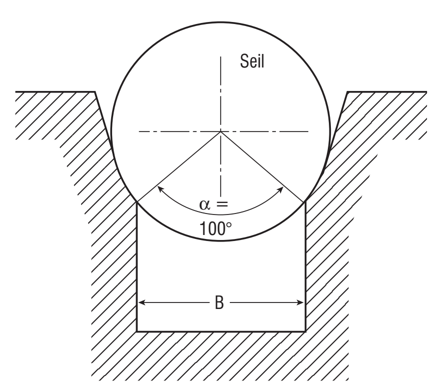

Figure 11: Rope and traction sheave, schematic view

traction-drive elevators with many varied shaft heights, roped hydraulic elevators and dumbwaiters with widely different car suspensions and counterweights, etc. Other contributory factors to the variety of constructions are tensioned balance ropes on high-speed installations and the ropes used in overspeed governor devices.

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 Figure 9 are special ropes not available from all manufacturers. It is also essential to bear in mind 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 Figure 11.

This procedure has a proven successful track record in this area. 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 six, eight and nine outer strands in undercut U-grooves with an extreme undercut angle of φ = 105° (Figures 12-14). The illustration on the right shows the rope with a rotated cross-section relative to the illustration on the left, but with a fixed rope center point. In most cases, many strands and a dimensionally stable full-steel rope constitute suitable construction.

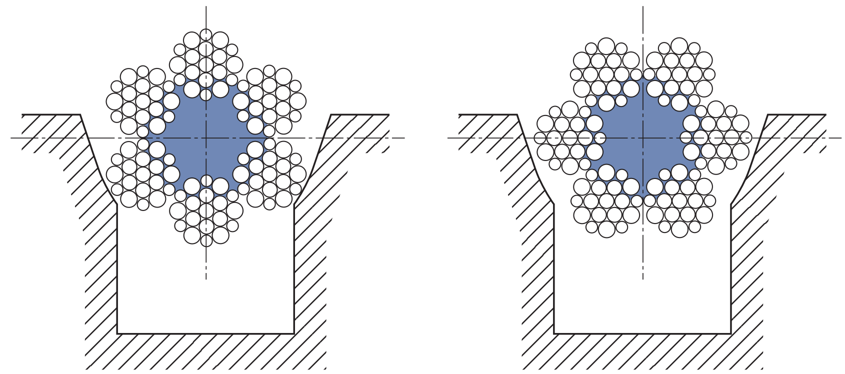

Figure 12: A six-strand rope with a 105° U-groove

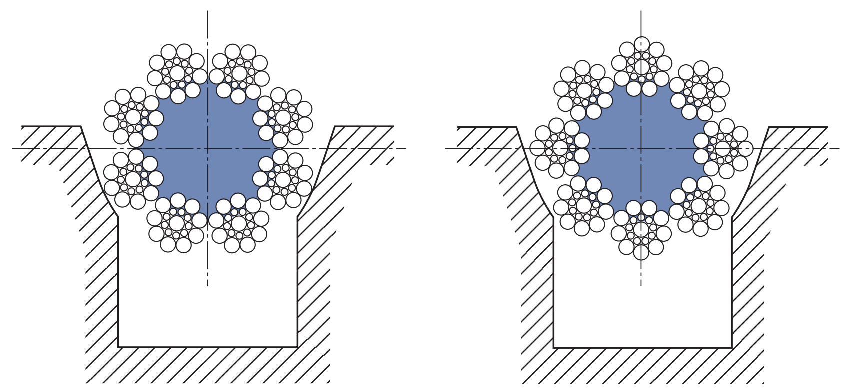

Figure 13: An eight-strand rope with a 105° U-groove

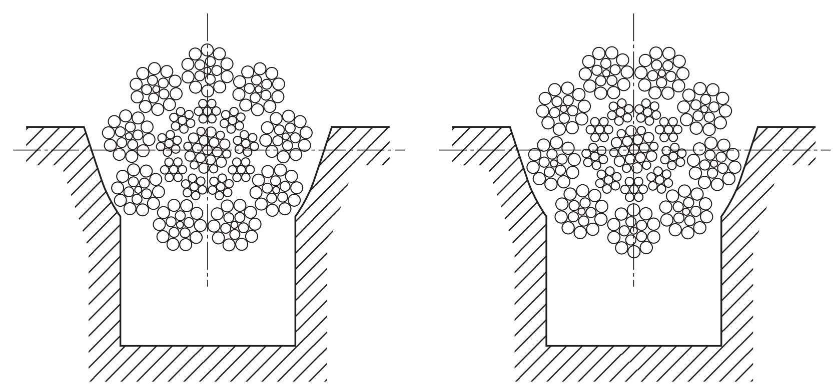

Figure 14: A nine-strand rope with a 105° U-groove

The appendix 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 a type of rope to an 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, are:

- The smallest possible degree of rope wear (thick wires, high wire tensile strength)
- A long rope life when running over sheaves (thin wires)
- Compatibility with the sheave (low wire tensile strength)
- The highest possible breaking force (fewer or thinner ropes with a high wire tensile strength)
- Low rope elongation due to rope shortening processes and ride comfort expectations (high metallic

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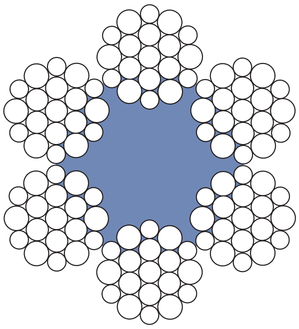

Figure 15

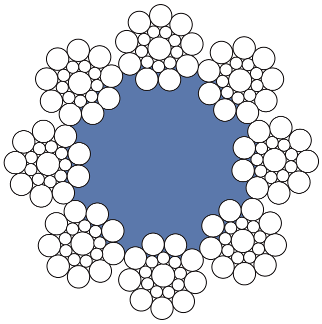

Figure 16

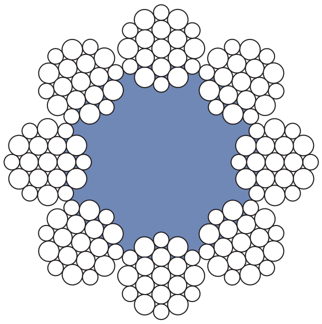

Figure 17

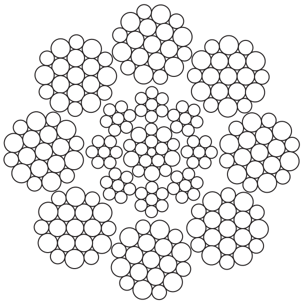

Figure 18

cross-section and top-quality fiber 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, the rope elongation factor increasingly determines the choice of rope with increasing shaft height.

A six-strand rope with fiber core (Figure 15) has the following benefits:

- ◆ A larger metallic cross-section, i.e., high breaking load relative to the rope diameter
- ◆ Relatively low permanent and elastic elongation
- ◆ A favorable price per meter

This type of rope's field of application should be in slow 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.

An eight-strand rope with fiber core (Figure 16) has the following benefits:

- ◆ Eight-strand ropes are rounder than their six-strand counterparts, creating more points of contact between rope and groove and, consequently, ensuring more favorable contact pressure conditions.
- ◆ They have a slightly more deformable cross-section, i.e., the rope adjusts more easily to slightly worn grooves.
- ◆ Eight-strand ropes have thinner wires than six-strand ropes of the same construction and diameter, i.e., the rope is less rigid and offers better fatigue bending characteristics.
- ◆ A median price per meter

This construction is, internationally, the most frequently used elevator rope. However, the 8 X 19 Warrington rope construction with natural fiber core (Figure 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 fibers used to produce the fiber core.

An eight-strand rope with a steel-wire core offers most of the benefits and very few of the drawbacks of eight-strand ropes with fiber core. Benefits include:

- ◆ Eight-strand ropes are rounder than six-strand ropes.
- ◆ Eight-strand ropes with steel cores keep their round cross-section in operation and are consequently suited for grooves with a large undercut.
- ◆ Eight-strand ropes of this type are more flexible and offer good fatigue bending characteristics.
- ◆ Little or no permanent or elastic elongation
- ◆ Low rope diameter reduction under load and over time
- ◆ High breaking load relative to diameter

The eight-strand rope offers an easy maintenance solution for high-duty elevators and is preferably used for rope lengths of 50-100 m. It is important to ensure that the rope termination (as for all elevator ropes) is secured against rotation. When used for extreme shaft heights, the ropes should untwist as little as possible during installation. The grooves of the drive sheave should be inspected when changing ropes, as these ropes will not adapt to a worn groove.

The Drako 300 T nine-strand elevator rope was developed in 1955 as probably the first elevator rope with a steel-wire core (Figure 19). Its benefits are:

- ◆ A very round cross-section with consequently low contact pressure between the rope and groove
- ◆ A large number of thinner wires with, consequently, very good fatigue bending characteristics. In addition, a special arrangement of the wires in the strands and the strands in the rope help to prevent wire crossing and reduces the danger of internal wire breakage invisible from the outside.
- ◆ Minimal permanent and elastic elongation and consequently good stop accuracy, even in high shafts

The nine-strand elevator rope is the best solution as a suspension rope for all elevator installations with large shaft heights and for traction-drive elevators with many deflection sheaves. It is important to ensure that the rope termination is secured against rotation. When used for extreme shaft heights, the ropes should untwist as little as possible during

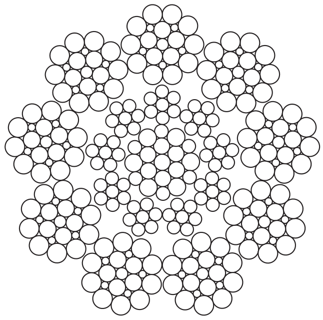

Figure 19

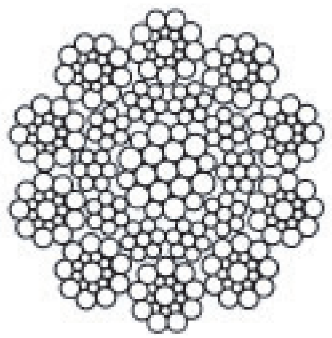

Figure 20

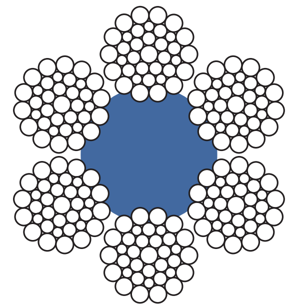

Figure 21

Figure 15: 6 X 19 Warrington with fiber core

Figure 16: 8 X 19 Seale with fiber core

Figure 17: 8 X 19 Warrington rope with natural fiber core

Figure 18: A Drako 250 T, 8 X 19 Warrington rope with an independent wire-rope core

Figure 19: A Drako 300 T, 9 X 25 rope with an independent wire-rope core

Figure 20: A Drako 310 T, 10 X 19 Seale wire with a parallel-laid core

Figure 21: A 6 X 36 Warrington/Seale noncompacted rope with fiber core

installation. It is expedient for a marking line to be provided on the rope as an aid for checking and, if necessary, correcting rope alignment. The grooves of the drive sheave should be inspected when changing ropes, as these ropes will not adapt to a worn groove.

Parallel-Laid Ropes

In the rope constructions illustrated so far, the rope core and outer strands are laid independently of each other in separate work processes. These ropes are durable and relatively insensitive to loosening as a result of external effects due to, for example, rope deflection. In a parallel-laid rope, the rope core and strands are laid in a single work process with the same length of lay, whereby the outer strands are placed in linear formation in a bed formed by two strands of the rope core (Figure 20). These ropes demonstrate a high breakage force and, in some cases, very high fatigue bending characteristics in laboratory testing with short rope lengths. However, they are sensitive to untwisting during installation and/or due to rope deflection, which is practically impossible to avoid in a 2:1 suspension or in double-wrap installations.

The use of plastic deflection sheaves can also be highly critical with this type of rope. Experience has shown that their use is unproblematic for ropes of up to around 40 meters in length. To the extent of which rope lengths in excess of this work satisfactorily depends on the experience of the respective rope manufacturer, and on the elevator installation itself.

Suspension Ropes for Roped Hydraulic Elevators

In the case of roped hydraulic elevators, the suspension ropes only run over deflection sheaves with round grooves. The absence of a drive sheave means that, in this instance, liberally lubricated ropes can be used. Furthermore, the use of round grooves makes for higher specific rope tensile forces. The typically used rope constructions here are six-strand ropes with fiber cores that have been exposed to a particularly rigorous pre-stretching process (Figure 15), and eight- and nine-strand ropes with a steel-wire core (Figures 18 and 19). The customary rope grade is 1770, and for ropes with a steel-wire core, occasionally even 1570 and 1570/1770.

Compensating Ropes (Tensioned Balance Ropes)

For traction elevators with rated speeds of more than 2.5 mps, tensioned balance ropes are stipulated as a method of weight compensation and to limit compensating weight jump brought about by the safety gear or the buffer. The suspension and balance ropes differ fundamentally in terms of their application conditions. The experience of past decades has culminated in special balance rope constructions permitting greater rope service life, quieter running and consistent rope lengths. These constructions are based on the following requirements:

- Improved lubrication
- An extremely round cross-section and consequently minimal contact pressure between the rope and groove
- A large number of thin wires and, consequently, extremely good fatigue bending characteristics
- The use of thicker and, consequently, fewer ropes and tensioning sheaves
- The use of thicker ropes with small D/d = 30 and, consequently, the ability to select flexible multiple-wire rope constructions (Figure 21)

Rope rotation cannot be excluded, as two tensioning sheaves are frequently arranged side by side. This can be triggered initially by alignment errors. Premature rope damage is possible – in particular, in the case of ropes with steel-wire cores. Ropes with a natural fiber core respond under typically low balance rope forces to changing humidity in the shaft (during construction, monsoon-esqe climatic conditions, etc.) by marked changes in length. Artificial fiber cores have been shown to provide a solution to the problem. Six-strand ropes with a high weight and artificial fiber core are recommended as balance ropes. For rope diameters of 13-25 mm, for instance, 6 X 25 fillers and (for larger nominal rope diameters) 6 X 36 Warrington/Seale constructions are used.

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Overspeed Governor Ropes

Governor ropes are essential functional elements of the overspeed controller, which engages the safety device when an overspeed situation is detected. The governor rope runs in the molded groove of the governor wheel. When the safety device is triggered, force is transmitted by friction between the rope and groove. Consequently, the amount of rope lubrication plays a significant role. In recent years, increasingly stringent demands have been made on breaking forces, which are increased as a result of larger rope diameters, higher rope grades or the use of full-steel constructions.

Generally, traditional six-strand rope constructions with fiber cores are used as governor ropes; in most cases, 6 X 19 Warrington ropes with fiber cores (Figure 15). These are generally ropes with a diameter of 6 mm or 6.5 mm in rope grades 1770 and, in some cases, even 1960. However, EN 81 excludes rope grade 1960 for use in suspension ropes but allows it for governor ropes. With increasing shaft heights and, consequently, rope lengths, the degree of rope strength required also increases. This results in the use of governor ropes with rope diameters between d = 8mm and 10 mm, and in some cases up to 13 mm with an 8 X 19 Warrington or 8 X 19 Seale with independent wire-rope core construction (Figure 18).

Some overspeed controllers do not decelerate the governor rope by blocking the governor wheel, but by means of closing brake shoes. The governor rope required for this design must not have excessively fine wires or strands. Although most of the above-described rope constructions have proven successful on many different overspeed governor designs, determining the correct type of rope construction to be used should lie with the overspeed governor manufacturer.

If ropes with fiber cores are used as governor ropes in particularly tall buildings, preference should be given to ropes with synthetic-fiber cores. However, in this case, these should be subjected to rigorous pre-stretching in order to limit their elongation in operation. This is particularly important given that governor ropes must be pre-tensioned, and that the tensioning path is limited. In the U.S., a certain proportion of governor ropes of strength class IRON are still encountered. The nominal tensile strength stipulated for the outer wires in these 700 N/mm^2 ropes is due to the brass brake shoes used in some speed governors. If steel ropes with higher rope grades were used in this case, there would presumably be a risk of excessively fast wear of the gripping components.

Rope Cores

Depending on the intended application, two different core types are used in elevator ropes: fiber cores made of natural or synthetic fibers, and steel wire cores. In elevator ropes, fiber cores made of natural or synthetic fibers are used. Natural fibers – generally sisal – are the most widespread for application in ropes. Due to their flexibility, ropes with fiber cores are able to adjust up to a certain extent to the relevant groove shape. The benefits of fiber cores are:

- Resistance to contact pressure
- Relatively low elastic rope elongation
- Low deformability

The drawbacks are:

- Good yarn qualities (i.e., thin, even yarns) are expensive and not easy to come by.
- The material absorbs moisture from the ambient air.
- Rotting is a possibility.

Fiber core can store lubricant. Its ability to absorb high quantities of grease can become a drawback. Storing too much lubricant during manufacture and giving off too much during operation result in fast rope-diameter shrinkage, as grease pressed out of the fiber core equates to a loss of volume in it.

Artificial fibers such as polypropylene (PP), which is popularly used for crane ropes and cable-car ropes, are also used for elevator cables. Ropes with this type of core are frequently involved where groove wear takes place on the sheave with a hardness of below 200 HB. Despite the many benefits, it must be borne in mind that fiber cores for elevator ropes with diameters of 7 mm and below made of natural fibers cannot always be manufactured to an adequate degree of diameter accuracy, no matter how meticulously produced. However, fiber cores made of polypropylene offer the benefit of immunity to rotting in humid environments and volume change caused by moisture absorption. The drawbacks of the PP core are its high elastic elongation and associated increased risk of rope impressions created in sheaves.

For governor ropes and balance ropes in installations involving long rope lengths – in particular in environments with high levels of humidity – chemical fiber cores would be the preferred choice. Natural fibers absorb moisture, making the core thicker and the rope shorter. Where longer governor-rope lengths are used, the height at which the tensioning pulley has to be fitted is not sufficient to compensate for excessive rope stretch. Polyamide fibers have produced excellent results as fiber cores for ropes running in round grooves due to their resistance to pressure. However, they come at a relatively high price. Figure 22 provides a comparison of the various fiber materials available for fiber cores in elevator ropes. Special controls are imposed on the evenness of the core and amount of lubrication. The influence of the rope core on the service life of ropes is frequently underestimated.

Steel-Wire Cores

Steel-wire cores increase the metallic cross-section and so reduce tensile stress in individual wires. Ropes with steel-wire cores are subject to lower elongation under the same load conditions as ropes with a fiber core. The steel-wire core can take on widely different forms (Figure 9) and be manufactured separately (independently) in a preceding work step prior to being formed with the strands (Figures 18 and 19). Another variant is to produce the steel-wire core and strands in a single work step, i.e., in parallel (Figure 20). The outer strands and the strands of the steel-wire core are placed similarly to the wires in parallel-laid ropes so that they make linear contact with each other.

One factor that all ropes with steel cores have in common is that the ropes must not be permitted to rotate during installation. Although ropes should always be laid with care, the negative influence of rope rotation in ropes with fiber cores is less pronounced than is the case in ropes with steel wire cores. While in ropes with fiber cores, all the strands become evenly longer or shorter when the rope rotates, in ropes with steel-wire cores, the outside and inside strands loosen to a different degree. This can result in pronounced differences in terms of load-carrying capacity and, consequently, serve to shorten service life.

Fiber Material	Absorption of grease without problems	Benefits	Drawbacks
Natural fiber Sisal	up to 17%	good grease absorption, pressure resistant, low longitudinal elastic elongation	damagable by high air moisture
Natural fiber Hemp	up to 22%	good grease absorption, good strand foundation, low longitudinal elastic elongation	lower diameter accuracy than Sisal, damagable by high air moisture
Natural fiber Jute	up to 20%		only for ropes smaller than 6 mm
Synthetic fiber Polypropylene	up to 12%	uniform thickness	not very pressure resistant, ductile, melts in high temperatures
Synthetic fiber Polyamide	up to 8%	very pressure resistant, uniform	low grease absorption, expensive, high longitudinal elastic elongation, fusibel
Synthetic fiber Aramid, e.g.	low	a fiber is as strong as steel, heat resistant up to 350°	difficult handling, very expensive

Figure 22: Rope core material comparisons

Lubrication of Strands and Cores

Wires, strands and cores are important components of the rope; however, they are only able to interact ideally in the presence of lubrication between the wires. The only reason a rope is able to bend so easily is because the wires are capable of displacement relative to each other. Lubrication reduces friction between the wires. However, in the case of elevators, it is totally false to assume "the more the better." On the contrary, an elevator rope subjected to frequent bending over sheaves over a service life of many years must be lubricated well but to a precisely controlled degree. It should be noted in this context that the lubricant does not impair the necessary traction, which is determined not only by the geometry of the traction sheave, but also by the coordinate of friction between rope and sheave. Thought should also be given to the risk of contamination by grease or oil spun off under central force.

Traction elevators differ considerably depending on their design in terms of traction reserve – in other words, the difference between the theoretically available traction and the traction used. Elevator ropes are seldom produced specifically for one installation. The rope manufacturer must always base calculation on the worst-case scenario and should only lubricate elevator ropes, as a rule, with relatively minimal quantity, with extreme care and as evenly as possible. Degreasing ropes to resolve the problem of excessive lubricant is extremely time consuming and cost intensive.

Due to the long service life of ropes in elevator installations, particular attention is attached to re-lubrication. Here, the same requirements apply as for initial lubrication, whereby steps must be taken to ensure that those used for initial and subsequent lubrication are chemically compatible. For application in traction elevators, lubricants containing bitumen are not ideal, as they tend to form highly viscous adhesive encrustations on both sheaves and ropes. Friction-reducing elements such as molybdenum sulfide or Teflon® particles should be dispensed with, as their influence on traction can be very difficult to predict and they unnecessarily add to the cost of the application.

Direction of Lay

A distinction is made when considering the direction of lay between right- and left-hand-lay ropes. As rule, elevator ropes are right-hand-lay ropes, i.e., the outer strands form

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a right-hand helix. As a result of twist due to load, a torque created by the attempt of the elevator rope to reverse the laying status under torsional load, elevator installations used to frequently be equipped with right- and left-hand-lay ropes in pairs. This allowed compensation of the forces acting on the guide rails of the car and counterweight resulting from the twist due to load. However, as these forces are only small relative to those generally absorbed by the guide rails, in modern elevator installations, priority is given to the requirement that all suspension ropes be as nearly identical as possible, i.e., should always originate from the same source of manufacture. The mixed use of left- and right-hand-lay ropes, which can only be produced using separate manufacturing processes, has generally been abandoned. In drum-driven elevators, the drum pitch must be selected to match the direction of rope lay, i.e., "right-lay rope – left-hand drum."

Regular (Ordinary) Lay and Lang Lay

In the same way as the strands in the rope, the wires in the strands can be laid in left- or right-lay wires. Regular or ordinary lay is used to describe a different lay direction for the outer strands in the rope and the wires in the outer strands. If the wires in the strand and the strands in the rope have the same lay direction, this is described as Lang lay. In regular-lay ropes, the visible outer wires approximately follow the direction of the rope axis. In Lang-lay ropes, the visible outer wires are inclined at a steep angle to the rope axis.

Ordinary-lay ropes are hard-wearing and easy to mount. They have only a slight tendency to untwist when hanging freely in the shaft. Their elastic elongation is lower than it is in the case of Lang-lay ropes. These benefits mean that the majority of elevator manufacturers exclusively use ordinary-lay ropes.

In round grooves, Lang-lay ropes achieve greater bending resistance than do ordinary-lay ropes. However, they are more sensitive to diagonal pull and have more stringent demands in terms of installation. Steps must be taken when hanging the ropes freely in the shaft to prevent untwisting, as otherwise the wires will work loose and result in premature rope damage. The degree to which Lang-lay ropes are accepted differs widely around the world. For example, while they are given equal status in the U.K., in Germany, their use is subject to certain provisos.

Lang- or Regular-Lay Rope?

An inferior-quality or carelessly mounted Lang-lay rope entails a substantially greater hazard potential than an inferior-quality, ordinary-lay rope. An elevator company aiming to change over to Lang-lay ropes should ensure that it chooses a design that has been thoroughly tried and tested over a number of years. Also, close examination of the traction sheave grooves must take place when considering the replacement of Lang-lay with ordinary-lay rope on an existing installation. The ordinary lay wires running in a different direction can wear the grooves if they have been imprinted by the Lang-lay rope.

Preformed Ropes

In preformed ropes, the inner tensions of the wires used in the strands and the strands used in the rope are reduced, with the result that when the rope binder is removed, pre-formed ropes do not spring open. This substantially simplifies the processes of cutting to length and installing. Preformed ropes are also known as low-tension or low-twist ropes. Preformed elevator ropes have become the standard design in Europe.

Pre-Stretching

Elevator ropes are pre-stretched in order to induce compaction of the rope structure, which otherwise only takes place with the first load cycles after hanging, prior to commissioning. This means that the permanent rope elongation (permanent rope stretch) that accompanies compaction of the rope structure is reduced, minimizing the amount of work involved in shortening the ropes after only a short period of use.

Experienced elevator rope manufacturers use suitable measures to achieve a pre-stretching effect during production by applying around 30% of the rope breaking force. More intensive pre-stretching calls for a separate work process. ISO 4344 restricts the maximum tensile force applied during pre-stretching to 55% of the minimum breaking force.

The most notable effect is achieved when pre-stretching eight-strand ropes with natural fiber cores. Here, 0.2% permanent rope elongation can be achieved, as the strands become (permanently) more deeply embedded in the fiber core. In the case of ropes with steel-wire cores, the effect of pre-stretching on permanent elongation is relatively low. In addition, the pre-stretching effect is partially lost due to handling of pre-stretched full-steel ropes during the hanging process.

Rope Diameter

Table 1 indicates the most commonly used rope diameters in Europe, the USA and Japan (East Asia). For certain European countries, the most commonly used suspension-rope diameters are additionally marked in each case. Beyond this, 24-mm ropes are also used in the high-rise sector. Although rope diameters smaller than 8 mm are not covered by the current version of EN 81-1, elevator installations using 6.5- and 6-mm ropes already exist. In the future, it will be possible to use suspension ropes of just 5 mm and 4 mm (such as the Drako STX series) operated on the basis of a separate approval certificate from a Notified Body. The development of rope diameters of such small proportions is being driven by the trend toward machine-room-less elevators with small, fast-running drive machines and the move to reduce drive torque levels.

Rope diameter must be measured within one layer and offset by 90°. If there is an even number of outer strands, measurement must take place over two opposite strands. For an uneven number of strands, measurement must take place over one strand and the opposite gap between strands. The mean value must be formed from the two diameters.

For elevator ropes (in particular, for suspension ropes for traction elevators), the tolerance requirements are more stringent than for other wire ropes in order to guarantee low-wear transmission of forces between the sheave and rope. According to DIN EN 12385-5, the limiting nominal diameter dimensions for traction elevators are: 0 to +5 % for suspension ropes with fiber core and 0 to +2% for full-steel suspension ropes. For suspension ropes used in roped hydraulic elevators, the applicable tolerance window is 0 to +5%. For small rope diameters, in some cases, greater than 1% tolerance is admissible.

A distinction is made between detachable and permanent rope terminations, of which only those illustrated in Figure 23 are regularly used in elevator construction. The terminations comply with the conditions of EN 81-1/1998, Section 9.2.3.

Rope diameter mm	inch	Europe Traction Susp. rope	Europe Roped hydraulic Susp. rope	Europe Governor rope	U.S. Suspension rope	U.S. Governor rope	Japan Tragseil
6		x[1]		x			
6.5		x[1]		x[2]			
8		x[2]	x	x			x
9		x					x
	3/18				(x)	x	
10		x[3]	x	x			x[7]
11	7/16	x[4]	x		x		
12		x					x[6]
	1/2				x[5]	x	x
13			x[2]	x	(x)		
14		x					x
15		x					
15.5		x					
16	5/8	x			x		x
	11/16				x		
18		x		x			
	3/4				x		
20		x					x
	13/16				x		
12	7/8				x		x

[1] Small freight elevators [2] most used in Germany [3] most used in France [4] most used in U.K. [5] most used in U.S. [6] most used in Japan [7] officially minimum in Japan

Table 1: The most commonly used rope diameters around the world

A termination with wire-rope grips in accordance with DIN 1142/EN 13411-5 is not listed nor recommended for safety-relevant applications. The requirement for securing against untwisting (rotation) after installation applies to all end terminations.

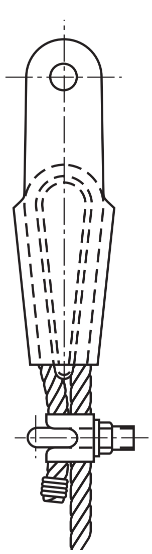

Figure 23: Rope terminations used in elevator construction: metal and resin socketing, aluminum ferrule with thimble, swaged terminal, symmetrical wedge socket EN 13411-7, asymmetrical wedge socket and rope eye with wire-rope grips

Metal and Resin Socketing

In Germany, metal and resin socketing is dying out as a method of end termination for elevator ropes, while in the U.S.[9] and Far East, this type of rope is still in frequent use. The socketing deviates significantly from EN 13411, Part 4[10] and can only be classed as safe in any respect in combination with small rope forces in the elevator. The benefit of socketing is its relatively lean construction (Figure 23). Alternatively, plastic socketing can be used.

Aluminum Ferrule

An aluminum ferrule termination as specified in EN 13411, Part 3[12] (formerly DIN 3093[11]) is very frequently used in Europe. It is mainly used in elevator construction in conjunction with a thimble[14] and eye bolt (Figure 23). This type of termination is frequently used in combination with a wedge socket at the other end of the rope. Aluminum ferrule is preassembled from the factory and cannot be mounted during rope installation. It provides an extremely secure termination, which (apart from a few exceptions such as the U.S.) meets with very broad acceptance. This makes it all the more regrettable that in certain countries, aluminum ferrule is met with a certain degree of distrust.

Swaged Termination

A swaged termination is a very slim construction that permits a wide range of different connection possibilities. Swaged terminations connect the steel sleeves and ropes permanently using the swaging

Continued

methods of pressing or rolling. The neatness of the finished connection makes this type of termination a favored option in open-design applications such as hotels. They are also popular where space is at a premium – for instance, car arrangements with piggyback suspension. Swaged terminations generally have to be secured against rotation. The insert depth of the rope in swaged terminations (and, consequently, the swaging length) is decisive to functional safety. By looking through the inspection hole provided at the end of the insert path, a check can be made to ensure that the end of the rope is inserted sufficiently far enough into the sleeve.

For terminations of this kind not specified by a standard, a type approval certificate issued by a Notified Body is required in accordance with EN 81 for a specific elevator application to verify that the system offers the same degree of safety in combination with the designated ropes as one of the regulated types of end termination.

Wedge Sockets

The symmetrical wedge socket described by EN 13411, Part 7[16] (formerly DIN 15315[15]) is commonly seen in Germany, the U.K., Italy and Japan (Figure 23). To secure the dead end of the ropes, only a grip in compliance with EN 13411, Part 5[18] (formerly DIN 1142[17]) may be used.

The asymmetrical wedge socket, in compliance with EN 13411, Part 6[19] (Figure 23) offers advantages in terms of rope guidance but has the drawback of a relatively bulky design. This can generally be compensated through the use of long eye bolts in staggered formation. Caution is called for in situations where slack is created. Unlike the symmetrical wedge socket, with this socket type, it is possible for the wedge to drop out. The dead rope end has to be secured with a rope grip in compliance with EN 13411-5 (formerly DIN 1142). It is not admissible for both ends of the rope (end under load and dead end) to be terminated together with this type of socket.

Wire-Rope Grips

European Lift Standard DIN EN 81 permits the termination of ropes with "three suitable" wire-rope grips. The use of wire-rope grips should be rejected for use in applications of such high safety relevance as lifts. In this regard, EN 81-1 urgently requires revision. The fact that the U.K. (the only country in which this type of end termination is still in widespread use for elevators) has prohibited its use in new installations makes the urgent need for revision all the more evident. Even more telling is the requirement according to DIN 1142/EN 13411, Part 5 that the rope diameters of interest to elevator constructors must be fitted with at least four grips.

The main problem inherent in termination using wire-rope grips is the necessity for regular retightening of the clamping screws. In addition, it is not possible to exclude the possibility that extreme rope vibrations could cause concealed rope damage at the first rope grip adjacent to the free rope length. Temporarily shortening a rope using a wire rope grip is an extremely hazardous exercise that should be avoided without fail: as the parts of the rope at which a wire grip has previously been located subsequently run over sheaves, there is a high likelihood of the rope fracturing prematurely at these points. Even if rope grips are fixed onto the rope as an aid to installation, this should only be done at areas of the rope that do not later run over rope sheaves.

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Learning-Reinforcement Questions

Use the below learning-reinforcement questions to study for the Continuing Education Assessment Exam available online at www.elevatorbooks.com or on page 153 of this issue.

- ◆ When is a six-strand rope with a fiber core used?
- ◆ When is a nine-strand rope with a steel-wire core used?
- ◆ What are parallel-laid ropes?
- ◆ What are compensating ropes?
- ◆ What are overspeed governor ropes?
- ◆ What is a fiber core?
- ◆ What is a steel-wire core?
- ◆ What do regular lay and Lang lay mean?
- ◆ Why are ropes pre-stretched?
- ◆ Which rope diameter tolerances are admissible?
- ◆ What's the main difference between a swaged terminal and a wedge socket?

ELEVATOR WORLD Continuing Education Assessment Examination Questions

Instructions:

- Read the article **"Steel Wire Ropes for Traction Elevators: Part Two"** (page 63) and study the learning-reinforcement questions.
- To receive **one hour (0.1 CEU)** of continuing-education credit, answer the assessment examination questions found below online at www.elevatorbooks.com or fill out the ELEVATOR WORLD Continuing Education Reporting Form found overleaf and submit by mail with payment.
- Approved for Continuing Education by **NAEC for CET® and CAT® and NAESAI for QEI**.

1. How many strands does the simplest elevator rope have?
   a. Three.
   b. Four.
   c. Five.
   d. Six.

2. How many strands does the most frequently used elevator rope have today?
   a. Three.
   b. Six.
   c. Eight.
   d. Nine.

3. Which requirements can *not* be complied with when using full-steel ropes?
   a. Less permanent elongation.
   b. Less elastic elongation.
   c. Better sound.
   d. Longer rope service life.

4. What is the application field of six-strand elevator ropes?
   a. High-duty elevators.
   b. Low-duty elevators.
   c. Slow freight elevators.
   d. A and b.
   e. B and c.

5. What is the application field of eight-strand elevator ropes with steel-wire cores?
   a. High-duty elevators.
   b. Elevators with rope lengths between 50 m and 100 m.
   c. A and b.
   d. None of the above.

6. What are overspeed governor ropes, in addition to being triggers for the safety device?
   a. Mostly traditional six-strand rope constructions with fiber cores.
   b. Ropes for which no lubrication is required.
   c. Very fast-running ropes.
   d. All of the above.

7. What are typical fiber-core materials?
   a. Sisal.
   b. Polypropylene.
   c. Polyamide.
   d. All of the above.

8. What is particularly important when installing steel-core ropes?
   a. Preventing rope rotation.
   b. Saving ropes from heat.
   c. Keeping ropes from touching each other.
   d. Removing ropes from magnetic fields.

9. How do the visible outer wires lie in a regular-lay rope?
   a. Approximately vertical to the rope axis.
   b. In a steep angle to the rope axis.
   c. Approximately in line with the rope axis.
   d. In several directions.

10. Which rope terminations are detachable?
    a. Metal socketing.
    b. Aluminum ferrule.
    c. Swaged terminal.
    d. Symmetric wedge socket.

ELEVATOR WORLD Continuing Education Reporting Form

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Continuing-education credit: This article will earn you **one contact hour (0.1 CEU)** of elevator-industry continuing-education credit.

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