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 rope diameter

Which rope diameters are used in the elevator sector?

The table 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 draft of EN 81-1, elevator installations do already exist using 6.5 and 6 mm ropes. In future, it will be possible to use suspension ropes of just 5 mm and 4 mm (Drako STX series), operated on the basis of a separate type approval certificate from a notified body. The development of rope diameters of such small proportions is being driven by the trend towards machineroom-less elevators with small, fast running drive machines and the move to reduce drive torque levels.

How is the diameter of elevator ropes measured?

The rope diameter must be measured within one plane 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 over one strand and the opposite gap between strands. The mean value must be formed from the two diameters.

Which rope diameter tolerances between ropes are admissible?

For elevator ropes, in particular 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 fibre 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 1 % greater tolerance windows are admissible.

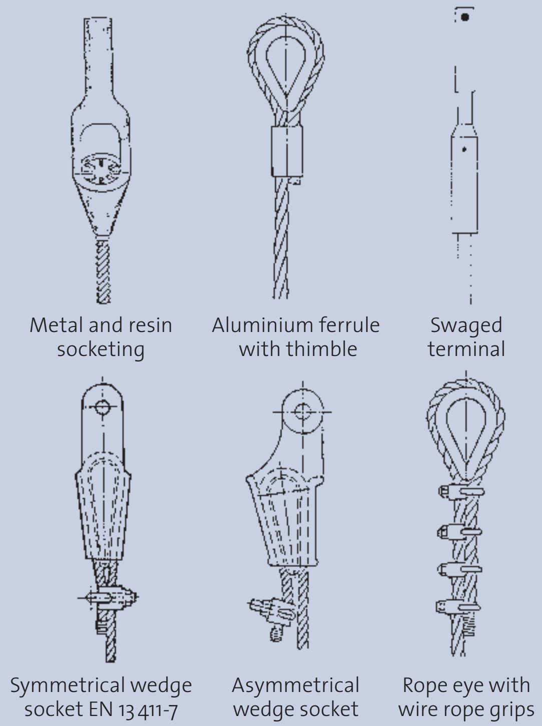


Fig. 23: Rope terminations used in elevator construction

Rope terminations

A distinction is made between detachable and undetachable rope terminations, of which only those illustrated in Fig. 23 are regularly used in elevator construction. The terminations comply with the conditions laid down by EN 81-1/1998 section 9.2.3.

Rope diameter		Europe			US		Japan
mm	inch	Traction sheave suspension rope	Ind.-hydraulic suspension rope	Governor rope	Suspension rope	Governor rope	Suspension rope
6		X1)		X			
6,5		X1)		X2)			
8		X2)	X	X			X
9		X					X
	3/8				(X)	X	
10		X3)	X	X			X7)
11	7/16	X4)	X		X		
12		X					X6)
	1/2				X5)	X	X
13		X2)	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		
22	7/8				X		X

1) Dumbwaiters
2) Most frequent in Germany
3) Most frequent in France
4) Most frequent in UK
5) Most frequent in US
6) Most frequent in Japan
7) Official minimum in Japan

A termination with wire rope grips in accordance with DIN 1142/EN 13411-5 is not listed and is not recommended for safety-relevant applications. The requirement for securing against untwisting after installation applies to all end terminations.

What is 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 USA [9] and in the 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, Fig. 23. Alternatively, plastic socketing can be used.

What is an aluminium ferrule?

An aluminium ferrule termination as specified in EN 13411 Part 3 [12] (formerly DIN 3093 [11]) is in very frequent use in

Europe. It is mainly encountered in elevator construction in conjunction with a thimble [14] and eye bolt, Fig. 23. This type of termination is frequently found used in combination with a wedge socket at the other end of the rope. The aluminium ferrule is pre-assembled from the factory, and cannot be mounted during rope installation. The ferrule is an extremely secure termination, which apart from a few exceptions such as the USA, meets with very broad acceptance. This makes it all the more regrettable that in certain countries such as the USA, the aluminium ferrule is met with a certain degree of distrust.

What is a swaged termination?

A swaged termination is a very slim construction which permits a wide range of different connection possibilities. Swaged terminations connect the steel sleeves and ropes permanently together using the swaging methods of pressing or rolling. The neatness of the finished connection makes this type of termination a favoured option in prestigious open-design applications such as hotels. They are also in popular use where space is at a premium, for instance car arrangements with piggypack suspension. Swaged terminations generally have to be secured against rotation. The insert depth of the rope in the 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 must be made whether the end of the rope is inserted sufficiently far into the sleeve.

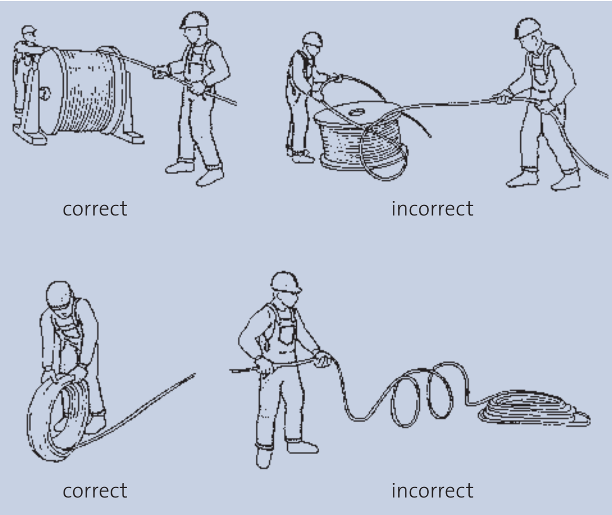
For terminations of this kind which are not specified by a standard, a type approval certificate issued by a “notified body” is required in accordance with EN 81 for a specific elevator application to verify that the system offers the same degree of safety in combination with the designated ropes as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

What is a symmetrical wedge socket for elevators?

The symmetrical wedge socket described by EN 13 411 Part 7 [16] (formerly DIN 15 315 [15]) occurs commonly in Germany, England, Italy and also Japan, Fig. 23. To secure slack ropes, only a grip in compliance with EN 13 411 part 5 [18] (formerly DIN 1142 [17]), may be used.

What is an asymmetrical wedge socket?

The asymmetrical wedge socket in compliance with EN 13 411 Part 6 [19] (Fig. 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 13 411-5 (formerly DIN 1142). It is not admissible for both ends of the rope (end under load and dead end) to be terminated with this type of socket.



What is a wire rope grip?

The European Lift Standard DIN EN 81 permits the termination of ropes with “3 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 in England, the only country in which this type of end termination is in widespread use for elevators, has now prohibited its use in new installations, makes the urgent need for revision all the more clearly evident. Even more telling is the requirement according to DIN 1142/ EN 13 411 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 which 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 ever be done in areas of the rope which do not later run over rope sheaves.

Elevator ropes in operation

How should ropes be stored?

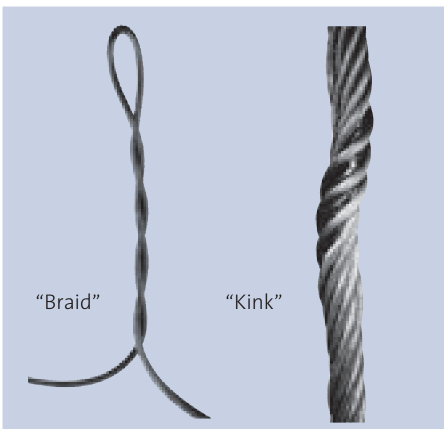
Elevator ropes are made up of bright wires which are not protected against corrosion. In order to achieve slip-free operation in the elevator, they are given a relatively minimal coat of grease. Consequently, over extended periods of storage prior to installation, ropes should be protected against corrosion. Ideally, they should be stored in a dry, frost-free and dust-free environment. Contact with cement dust or sand should be avoided in particular. When covering ropes for their protection, care must be taken to ensure adequate ventilation in order to prevent the formation of condensation, for instance where temperature conditions fluctuate.

How can ropes be unrolled for mounting?

The ground rules for rope mounting must be observed without fail. By removing from the side via the reel coupling or from the coil strap, the rope is uncoiled or coiled depending on the direction of lay. This twisting action brings about a change in the rope structure which can no longer be corrected. In the case of ropes with steel core, this type of forced rotation creates uneven strand lengths. The result is an uneven distribution of load in the rope bundle and the emergence of strands which have been extended beyond their normal length.

What is the reason for kink formation and how can it be remedied?

Carelessness, for example during unrolling, can frequently cause internal torsion in the rope (twist). If this effect turns the rope into a braid (left), then this can only



be remedied by turning the end of the rope. Violent rotation at the braid itself or pulling on the rope will practically always culminate in the formation of a kink. The resulting damage makes the rope unusable, and it must be replaced.

Why do ropes untwist?

Where long lengths are involved, a rope can untwist just under its own intrinsic weight when hanging freely in the shaft without having been secured against rotation. The same effect occurs if the rope is pulled upwards using a thin auxiliary rope. Lang lay ropes, ropes with steel wire core and in particular double parallel ropes are especially susceptible in this context. They react extremely sensitively if commissioned when in this condition. The loosened rope is incapable of absorbing loads evenly distributed over all the rope elements as intended by the design, and can be destroyed as early as the very first load cycles. Consequently, this type of rope is supplied with a marking line which makes incorrect rotation easily recognizable and provides a way of realigning ropes during installation.

What are the “lurking” dangers inherent in rope installation?

Sharp concrete or steel edges represent a major hazard for ropes. If they are drawn over this type edge under load – and in some cases the intrinsic weight of the rope can be sufficient – they will sustain permanent damage. This type of damage is evident in the rope when in an unloaded condition by a corkscrew-like deformation, which when under load is almost impossible to detect. To avoid this hazard, rollers or at least rounded wooden beams should be used for rope deflection.

Sandy or dusty surfaces are highly damaging for ropes. The lubricant on the surface of the rope sticks to the loose dirt particles and forms a rough layer, which damages both the rope and the sheaves during operation. This effect can also compromise smooth running, as large dirt particles particularly cause the ropes to run unevenly off deflection and traction sheaves, resulting in rope vibrations.

Some kinds of damage caused by unsuitable installation methods become evident after only a relatively short period of operation. The ropes demonstrate horizontal wear lines in parallel formation in certain areas, while other parts of the rope are almost intact. One cause for this phenomenon is the use of an unsuitable fixture for tensioning the ropes, for example in order to measure the weight of the car or the counterweight. The resulting rope deformation, and in certain circumstances additional kinking, result in local damage in the form of wire break nests, rendering the rope due for immediate replacement.

How does the drive arrangement affect the rope?

Just one example: The elevator drive system is arranged as shown in Fig. 24 for a variety of reasons. The reduced space requirement comes at a price: The ropes are bent in opposite directions, which severely compromises rope service life.

Another problem inherent in this arrangement is brought about by the horizontally running ropes, which have a tendency to vibrate. The vibration energy is concentrated at the point at which the ropes run onto the sheaves, so increasing the internal mechanical tensions in the rope. This additional stress results in premature fatigue of the wires, culminating in wire breakage. The vibrations occurring in the horizontal area of the rope following deflection produce vertical vibration of the car and the counterweight, creating an obvious detrimental effect on ride comfort.

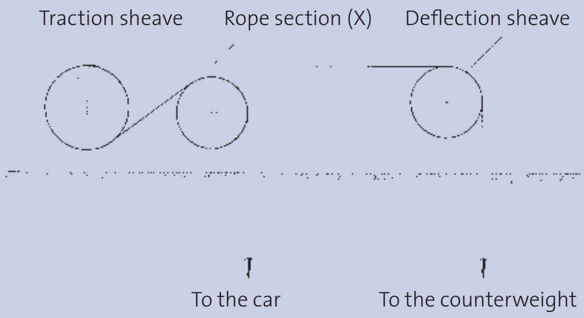


Fig. 24: The laterally positioned machine

In the case of elevators with a 2:1 suspension, the individual deflection sheaves are rotated by up to 90°. Depending on the construction and the resulting deflection points, the ropes may have a tendency to vibrate and impact on each other. This type of impact does not of necessity result in a reduction of service life, but it does create a perceptible noise to passengers in the elevator car. Another problem encountered by ropes is illustrated in the adjacent diagram. The ropes do not make central contact with the deflection sheaves, but are slightly offset. Depending on the properties of the grooves (aperture angle, surface roughness), this circumstance causes the ropes to rotate. The possible reaction of the rope to this phenomenon is influenced by its structure (Lang lay, regular lay). Under unfavourable circumstances, a Lang lay rope can become untwisted, whereby the strands also offer no resistance to the rotation. In the worst case scenario, a regular lay rope can be untwisted to the

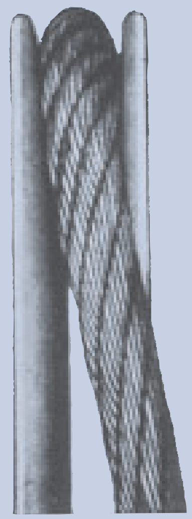


Fig. 25: Lateral deflection when running over a sheave (exaggerated for illustrative purposes)

point where the wires in the outer cores block this rotation process. Although comparatively speaking this is the less critical of the two situations, it should also be avoided.

When using ropes with a steel core, assessment of the external torque must be carried out in a similar way. An IWRC rope will always work against torque effect, either by means of the inner or the outer section. In the case of parallel laid full steel rope (PWRC) under unfavourable circumstances, the rope bundle can be permanently destroyed, resulting in strands emerging from the inner section of the rope. This risk highlights once again the urgent necessity for securing ropes against rotation in an elevator installation through the use of end terminations.

Lateral arrangement of the traction drive

Positioning the machine laterally at the bottom results in more pronounced rope deflection than is the case with the machine positioned above. Due to the extreme rope length, more frequent shortening may be anticipated. The high number of sheaves required exerts a negative impact on service life. According to EN 81-1, all sheaves count which are travelled over by the same section of rope which also runs over the traction sheave.

Positioning the machine laterally at the top reduces the necessary rope length compared to a bottom positioned machine. This benefit is countered by the fact that with this drive arrangement, all the sheaves must be taken into account when calculating the anticipated service life. In installations entailing particularly “angular” rope guidance with a correspondingly high number of sheaves, deficiencies can arise in terms of traction. Although this does not bring about uncontrolled car movement, it does cause occasional spinning of the traction sheave under the rope.

How does rope tension affect elevator ropes?

When designing and calculating elevators, the assumption is made that all the ropes proportionally transfer the same tensile force. In practice, this hardly ever happens. Deviating relative rope tensile forces are practically unavoidable. In installations involving great shaft heights, the frequently deployed method of pulling or pushing on the rope is no longer adequate. Newly developed rope tension measuring devices provide assistance here, offering a method of adjusting the rope tensile force to an even level. The adjacent picture shows a multiple measuring device in practical application. Uneven tension levels bring about different degrees of contact pressure on the grooves of the traction sheave, resulting in corresponding differences in rope slippage. In some cases, this brings about uneven wear in the grooves and ropes. Consequently all ropes should be tested after an initial operation phase for even load. Experience has shown that this inspection should be carried out after 4 – 6 weeks. In some cases, delaying this inspection has resulted in premature wear of ropes and/or sheaves.

Which types of rope vibration occur in the elevator?

Rope vibrations bring about noise development in the elevator and also a possible reduction of service life.

Transversal rope vibration can be approximately calculated using the following formula [20,21] for a vibrating wire:

$$f\,[\mathrm{Hz}] = \frac{n}{2 * l} * \sqrt{\frac{F}{q}}$$

with

f = vibration frequency,
n = 1 basic vibration,
n = 2, 3 ... for the harmonics,
l = Length [m],
F = Rope force [N] and
q = Weight per metre of the rope [kg/m].

This type of transversal rope vibration – as described in the context of drive position-related issues – is caused by factors such as horizontal rope alignment or interlocked wire guides. Conversely, vibrations in the direction of the rope axis are caused by stick-slip rope movements on the traction sheave, due to pitch errors in the transmission or errors in the electrical governor. The interaction between the rope and groove geometry when the rope runs off the traction sheave can also bring about vibrations.

Can vibration be eliminated or reduced?

Initially, the installation should be inspected to ascertain the condition of rope lubrication and evenness of load, and these factors corrected if required. Another check refers to measurement of the running diameter of the rope at the traction and deflection sheaves. Slight eccentricity can result in intrinsic vibration of the ropes in the case of an unfavourable combination. The loss of ride comfort this entails is clearly tangible.

A vibrating system can be “retuned” using certain selective measures, such as selecting a higher weight per metre, or changing the rope rigidity. Replacing an 8 x 19 construction with fibre core by 6 x 19 ropes with fibre core has often proven successful as a remedy to this problem.

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