ELEVATOR ROPES: SELECTION TO SUIT THE TYPE OF INSTALLATION

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ABSTRACT
Comparing the types of hoist and governor ropes for elevators around the world, it becomes obvious, that some longtime approved rope designs are not common every-where.
Approved variations, by no means complete, with their advantages and disadvantages are shown.

1 INTRODUCTION

A lift manufacturer, who is producing lifts not only in a small field of application, would be good adviced, to have some real different rope designs available, in order to solve different tasks. Additionally such a big company should also check the types of ropes, which all its own branches are using country-wide or even worldwide. Very often, a reasonable reduction of rope items (diameter, construction, rope grade), made with the full knowledge of the possibilities, will help to reduce costs.

2 The approved possible variations

To consider are:
- the rope itself, in regard of
    - diameter
    - number of strands
    - type of lay
    - direction of lay
- the strand with its
    - constructions
- the wire, in regard of
    - material
    - tensile strength grade
    - finish
- the core
    - material fibre
    - material steel wire
- the lubrication
    - amount and type.

3 The rope

3.1 The diameter

Here each lift company should establish a selected program of rope diameters in use for new installations and stick to that. The unnessessary big number of lift rope diameters, today existing in Europe, should be reduced step by step, when the installations are modernized. Fig. 1 shows the usual rope diameters in Europe and USA. There are more in the catalogues of the manufacturers. The respective national most common hoist rope diameter is marked for Finland, France, Germany and UK.

diameter inch	diameter mm	Europe governor	Europe hoist	USA hoist	USA governor	Europe roped hydraulic
7/8	22		X	X		
13/16				X		
	20		X			
3/4			X	X		
	18		X			
11/16				X		
5/8	16		X	X		
	15,5		X			
	15		X			
	14		X			
1/2	13		X 4)	X	X	X
	12		X			
	11		X 2)			X
	10		X 1) 4)			X
3/8				(X)	X	
	9		X			
	8	X	X 3)			X
	6,5	X	X			
	6	X	X			

1) France
2) UK
3) Finland
4) Germany

Fig. 1 Common hoist rope diameters in elevators

Concerning the barriers (legal or by longtime habit) against hoist ropes smaller than 1/2" (respectively 12 mm): these restrictions are not covered by European experience, see fig. 1.

3.2 The number of strands in the rope

3.2.1 6-strands

The 6-strand rope with fibre core had been longtime - 40 years ago - the common hoist rope, see fig. 2.
The abbreviated evaluation:

advantages	disadvantages
big metallic cross-section, i.e. high breaking force compared to diameter/ relatively small permanent and elastic elongation/ low price per meter	big wire diameters, i.e. inflexible, i.e. reduced fatigue bending life/ reduced number of contact points rope to groove, i.e. high pressure

Summary: sufficient for low duty traction elevators,
good for roped hydraulic elevators (round grooves!),
the normal governor rope,
as hoist rope for high rise, when there is no steel core rope available.

3.2.2 8-strand rope with fibre core

The 8-strand rope with fibre core is without doubt the worldwide most common lift hoist rope, see fig. 3.

In short terms:

advantages	disadvantages
rounder than 6-strand, i.e. more contact points rope to groove/ deformable in cross-section: i.e. the new rope adapts a little bit to worn out grooves/ wires smaller in diameter: i.e. flexible, good fatigue bending characteristics/ medium price per meter	high permanent and elastic elongation, together with relative big reduction in diameter/ very dependant on quality of fibre and fibre core/ low breaking force compared to diameter/ deformable cross-section: disadvantage with wide undercut U-grooves.

Summary: best solution as hoist rope for the "normal" traction lift.

3.2.3 8-strand rope with steel core

The 8-strand rope with steel core has most of the advantages and only a few of the disadvantages of the 8-strand rope with fibre core, see fig. 4.

advantages	disadvantages
rounder than 6-strand flexible, i.e. good fatigue bending characteristic/ low permanent and elastic elongation/ low reduction in diameter/ high breaking force compared to diameter/ remains round: good for wide undercuts.	remains round: no adaption to a little bit worn out grooves/ higher in price per meter than fibre core rope./Mounting: Attention! Ropes should not be allowed to open up./ Terminations must be secured against rotation.

Summary: Good for: Traction hoists of medium high shafts (50 m upward) with medium frequency,
all roped hydraulic lifts with heavy duty,
governor ropes for high speed lifts (high speed: i.e. high shafts).

3.2.4 9-strand rope

The lift rope, with 9 outer strands, only possible with steel core (too deformably with only fibre core) is in application since 40 years in Germany, but is only slowly becomming familiar to lift companies outside Europe, see fig. 5.
The reasons why are obvious: For most of the worldwide users steel core is unknown. The additional suggestion of 9 outer strands: that's too much in one step.

advantages	disadvantages
very round cross-section, i.e. small pressure in the groove/ many wires, i.e. flexible, very good fatigue bending life/ small permanent and elastic elongation: the car is more connected to the machine/ remains round (see 8-strand rope + steel core).	remains round (see 8-strand rope + steel core)./ Mounting: see 8-strand rope + steel core)/ when babbitted sockets: it needs training to get the increased number of strands in the socket body/ high price per meter.

Summary: for high rise lifts
for lifts with many sheaves
for roped hydraulic lifts with heavy duty.

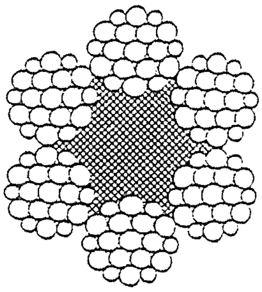

Fig. 2
6-strand rope
with fibre core

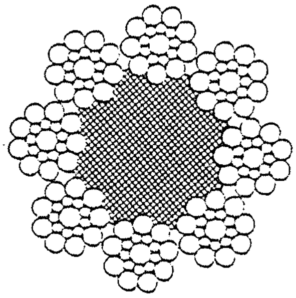

Fig. 3
8-strand rope
with fibre core

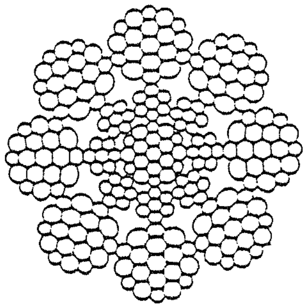

Fig. 4
8-strand rope
with steel core
DRAKO 250 T

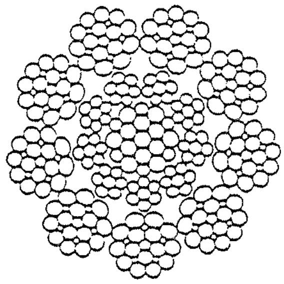

Fig. 5
9-strand rope
with steel core
DRAKO 300 T

3.3 Type of lay

3.3.1 Ordinary lay

Most of the lift-companies are only using ordinary lay ropes, see fig. 6. Ropes with this type of lay are easier to mount: the tendency to open up, when free hanging in the shaft, is relatively small. Such ropes are also easier to produce in good quality on the, for competetive prices obligatory, fast tubular closing machine.

3.3.2 Lang lay

It is mentioned a long time by especially American rope experts and also covered by f.i. steel mill crane experience in Europe, that lang lay ropes, see fig. 7, have better fatigue bending characteristics. Each wire is contacting the flank of the round groove longer and more adapted. Inner and outer pressure is reduced. Advantage in lifts: It is possible, that lang lay ropes have a better grip on nonmetallic drive sheaves (higher friction factor). But for traction lifts with their V- and undercut U-grooves we have also other points to regard. Disadvantages of lang lay are: Allergic against deflection angles, vulnerable by uncarefull mounting. The elongation of these ropes is considerably bigger than the one of ordinary lay ropes (only valid for ropes with fibre core). Discard criteria: Evaluating the different number of repeated visibility of a single wire in ropes of different type of lay, national and international standards allow as discard criterium for ordinary lay rope twice the number of broken wires than for lang lay ropes.

Summary: There must be strong reasons for a company to decide to use lang lay ropes.

Fig. 6 : Right hand lay rope, ordinary lay

Fig. 7 : Right hand lay rope, lang lay

To make the difference in elongation of the mentioned rope constructions (classes) visible, fig. 8 shows load-elongation-curves of 13 mm (1/2") ropes. Curve 1 is always the first loading of the new rope up to 10 % of Minimum Breaking force (MBL). Then the rope is loaded 10 times up to 50 % of MBL. Curve 2 follows with the same load as curve 1. The steepness of the curves is a measure for the elastic elongation (bouncing of the car etc.) and the horizontal difference between curve 1 and 2 is a certain measure for the permanent elongation (number of rope shortening operations etc.)

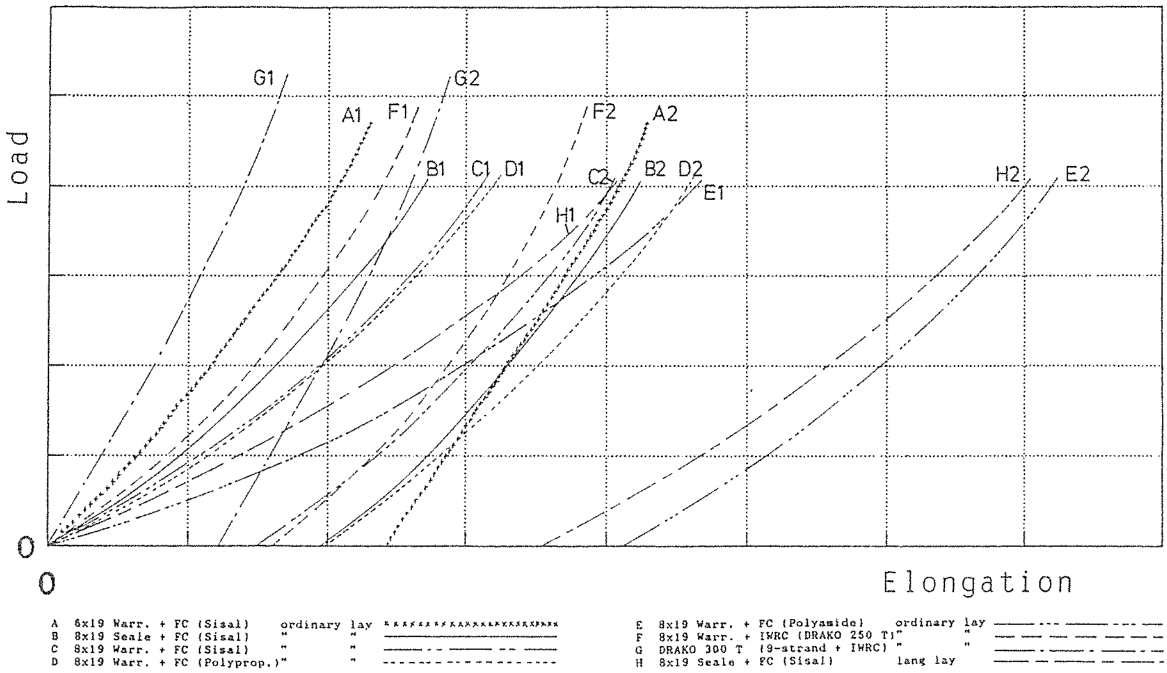

Fig.8: Load-Elongation-Diagram
ropes: 13 mm (1/2"). Maximum load: safety factor 10
Curve 1 acc. first loading
Curve 2 measured after ropes loaded 10 times up to 50 % MBL

3.4 Direction of lay

Only in very special cases - f.i. unguided or only wire-guided counterweight - it should be considered to take right and left hand lay ropes. The influence of the rope torque on the guiding forces on normal lifts with guide rails is extremly small. It should be much more important to have a set of ropes out of one production length (left hand and right hand can't be out of one production run).

4 Strand construction

4.1 Seale

The most common strand construction worldwide is Seale 9-9-1, see fig. 9.

This has at least two reasons:

- from the users side: lift ropes are known to get abrasion in usage and the big outer wires of Seale have a big metallic area to abrase before the wires will break.
- from the ropemakers side: Seale is easy to produce: only 3 different wire sizes necessary. Even if the geometry is wrong, the strand surface looks fine.

4.2 Warrington

When ever a comparison of fatigue bending life in round groove is made, ropes of Warrington strands /(6+6)+6+1/, see fig. 10, are winning in front of Seale ropes with 20 to 40 % more lifetime. This is due to more and smaller wires per strand.
It must be taken into account, that in lifts there is not only abrasion but also a lot of fatigue bending, especially in lifts with double wrap drives or in roped hydraulic lifts.

So in UK and Germany we have both: Seale and Warrington as strand constructions for lift hoist ropes.

Disadvantage of Warrington construction from the ropemakers side:

- 4 different wire sizes necessary for good geometry,
- each geometry distortion is feelable on the strand surface (rough as a rasp).

4.3 Filler wire

Filler wire strand construction, see fig. 11, is an especially fatigue bending withstanding wire configuration. This is covered by the fact, that f.i. the rope 8 x 21 Filler wire + fibre core (strand: 10+5F+5+1) is part of the Canadian lift rope standard. Hoist ropes, bigger in diameter than 16 mm (5/8") with 6 to 9 outer strands should have at least Filler wire strands (12+6F+6+1) because of better flexibility.

Disadvantages: Very vulnerable by geometry defects, especially, when the Filler wires itselves have not the nominal diameter. So the recommandation is given, not to take Filler wire strands for ropes below 10 mm diameter.

4.4 Warrington-Seale

Warrington-Seale is built up by three wire layers and is a mixture of Seale and Warrington, see fig. 12.

For lifts, the typical low purpose crane rope construction 6x36 Warr.-Seale with fibre core is only and common for tensioned compensation ropes. Reasons: Too hurtable by geometry faults and/or by drive sheave clamping grooves and/or by lack of inner lubrication.

Only well lubricated ropes 6x26 Warrington-Seale (strand: (10+(5+5)+5+1) have proofed to be a solution for drives with a lot of nearby arranged sheaves and reverse bendings. Attention: There must be more built-in traction reserve than usual, because of the necessary higher amount of lubrication.

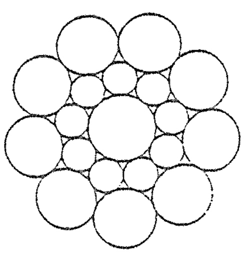

Fig. 9
Seale-type strand
(9+9+1) wires

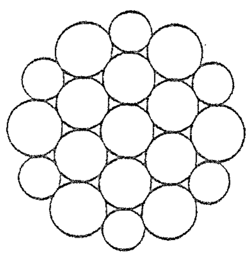

Fig. 10
Warrington-type strand
((6+(6)+6+1) wires

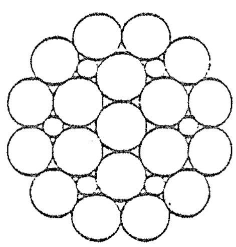

Fig. 11
Filler wire-
type strand
(12+6F+6+1) wires

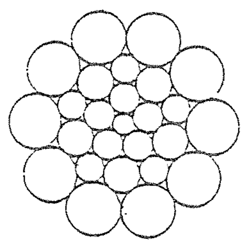

Fig. 12
Seale-Warrington-
type strand
(10+(5+5)+5+1)
wires

5 Wire

5.1 Material

The normal steel wire material is well known and without discussion the best one also for lift ropes.

Sometimes there are requirements, f.i. from architect's side, for stainless steel wire ropes. But such ropes are not to recommend, because ropes of stainless steel wires are very poor in fatigue bending and very high in price. Additionally a warning is necessary: The normally off handlers stock available stainless steel ropes are in regard of geometry and lubrication no lift ropes.

5.2 Tensile strength grade

Here the world lift industry has a world of opinions, out of three reasons:

- out of tradition, not of knowledge, or
- due to the sometimes minor quality of drive sheave material ("soft"-wire plus poor sheave material:hopefully no imprints)
- due to allowance, or better said, lack of restriction of excessive pressure between rope and groove (explanation: with excessive pressure, often only "soft" wires help to avoid wear or imprints).

  For the nominal tensile strength grades of the wires in an outer strand, there are 2 basic alternations existing:

  mono tensile:
  - all wires have the same grade
  - the nominal rope grade is identic with the nominal wire grade

  and

  dual tensile:
  - the outer wires have a lower grade than the inner wires
  - the nominal rope grade is between the nominal grades of the inner and outer wires.

The existing range of nominal tensile strength grades for hoist and governor ropes is:

Rope grade N/mm²	Name	National or international standard and remark
700	Iron	to avoid, only for replacement jobs
1200	Traction steel	USA
1180/1770	dual tensile	to avoid, only for replacemant jobs
1270/1770	dual tensile	Canadian Standard CSA G 387
1325	Grade E	JIS G 3525
1370/1770	dual tensile	ISO Standard 4344
1510	high rise traction steel	USA
1570	single tensile	ISO and national European Standards
1690	extra high grade traction steel	USA, seldom used
1720	grade 1720	Canadian Standard CSA G 387
1770	single tensile	ISO and national European Standards
1960	single tensile	Europe, round grooves

When the wire mill is using the appropriate basic material (percentage of Carbon and pureness of steel has to fit to the wire tensile strength) in the range of 1350 to 1800 N/mm² wire grade, today is nearly no difference in fatigue bending behaviour.

To proove that, testers should use ropes of same construction, same diameter and with same rope load. But people are choicing high grade ropes, just because they want to load the rope higher.

Example: Rope diameter: 12 mm
Construction: 8x19 Seale + fibre core
Safety factor: f.i. 16

Rope grade		load	
N/mm²	PSI	KN	lbs
1325	192110	3,61	7970
1770	156630	4,82	10640

Difference in allowed load: approx. 33 %

It is obvious, that a difference in load of such percentage leads to a similar higher pressure rope to groove and wire to wire inside the rope. A reduced service life is the result. So if there is a need of using ropes with higher rope grade, f.i. 1960, and accordingly higher loads, it would really help the rope to reach good rope service life, when the installation is designed with sheaves visibly bigger than 40 D/d, to reduce pressure and bending stress.

5.3 Wire finish

The normal lift hoist rope is made of bright wires with no coatings. For outdoor installation galvanized ropes are to recommend, provided, they are really made and lubricated for elevator purpose, preferably lubricated with a water resistant lubricant. In tropic zones, with the possibility of water filling up the shaft pit, also governor ropes should be galvanized. The only disadvantages of such galvanized ropes: the higher price (approx. 10 %) and sometimes longer delivery times.

6 Core

6.1 Material fibre

Most of the worldwide used lift hoist ropes are fibre cored ropes and the opinion is unique, that the material for the core should be natural (vegetable) new hard fibre, i.e. manila or sisal (ISO 4366).

Natural fibre cores:

advantages	disadvantages
good pressure resistance, not elastic compressible (reduced elastic rope elongation), not so deformable.	good qualities of material (small diameter yarns of even size) are high in price and often not available, soaks up humidity from the environ, rot possible.

Against widespread opinion the ability of storing more grease is not to recognize as an advantage of natural fibre material. To use this ability means, to reduce the rope diameter unnecessaryly quick by pressing out grease = volume.

Manmade fibres like Polypropylene (PP), common for hoist ropes in cranes and arial rope way haulage ropes, have been tried also for lifts. Everybody is invited to make his own experience, especially on "soft"-sheaves.

On the other hand, with small diameter (7 mm and less) hoist and governor ropes, it is not possible even with great care, to make sufficient perfect natural fibre cores. In humid environ (monsoon zones) governor ropes change length sometimes drastically. Here ropes with manmade-fibre cores are to prefer.

Manmade-fibre cores:

advantages	disadvantages
no rot in humid environ/ no change in volume in humid environ.	big elastic stretch, therefore higher possibility for imprints in sheaves.

6.2 Material steel wires

Steel wires as material for lift rope cores (steel cores) are explained in their advantages and disadvantages in section 3, ropes.

Mixed cores of fibres and steel wires or solid polymer coverings or fillings together with steel wires are existing, but mostly found of less advantage, but of relatively high price, together with a complicated production process.

7 Lubrication: Amount and type

Selecting ropes, also the lubrication should be checked. For drumlifts and roped hydraulic lifts, much grease in and on the ropes will increase fatigue bending lifetime and will cause only some minor problems with grease all over the machine room. More care is to take for traction lift ropes. As much grease as possible would also here be good for the rope, but how much is possible?

This depends on the habits of the lift company: How much traction reserve is provided in the machine calculation? So a good policy would be: Better a little lack of lubricant, than too much, because, if there is a need for more lubrication, the maintenance man can apply it.

The original lubricant, the rope comes with, should be not too sticky, never containing bitumen or filling materials or friction reducing itemes as molybdenum sulfide or teflon particles.

8 Summary

For the normal all-days-business, the 8x19 rope with fibre core will do it excellently. For more sophisticated jobs, the user should have knowledge about approved possibilities. The listings of pros and cons to all these variations are personal opinion of the author, but covered by experience as longtime and successfull supplier of a lot of the mentioned items.

A warning is necessary: All these variations in rope design are now at least 20 years in application. When new and so-said better rope constructions are advertised, the carefull user should take into consideration, that it needs at least 10 years and a lot of successfull running installations of different type, to be certain to have a really approoved rope.

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