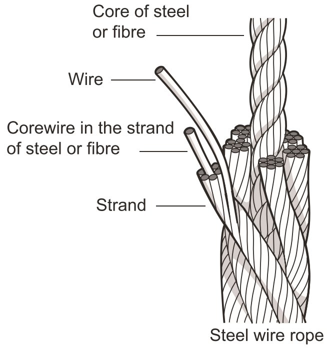
Technical description

What is a Steel Wire Rope?

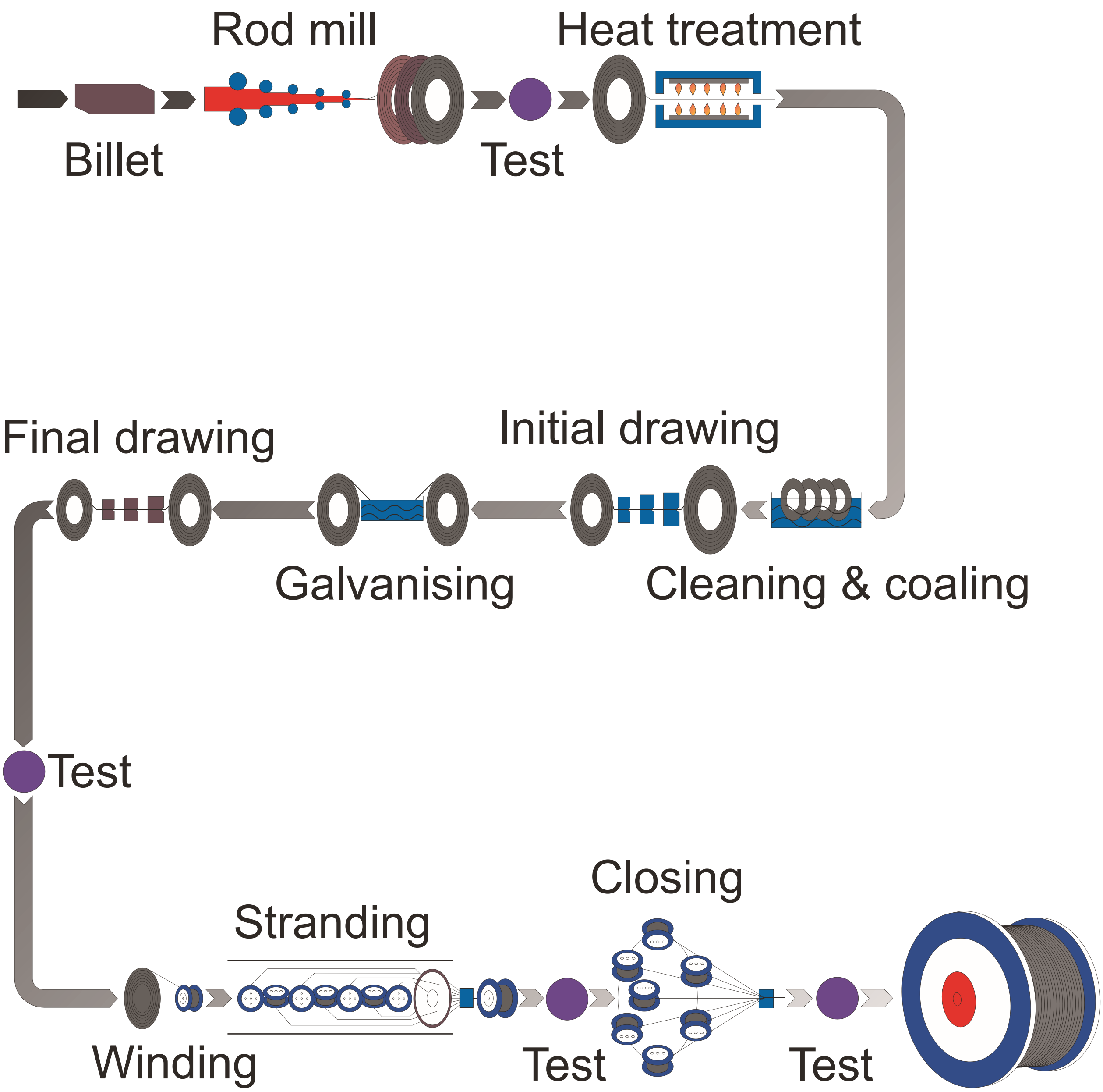
A steel wire rope is made up of individual steel wires spun into a strand. A number of strands are closed over a central core to make up a rope. The number and size of wires will determine the best compromise possible between large wires for maximum corrosion protection and resistance to abrasion, and smaller wires for the required flexibility and handling.

The construction of a steel wire rope is expressed according to the following:

e.g **6x36-FC**
6 is the number of strands in the steel wire rope
36 is the number of wires in the strand
FC is the type of the core

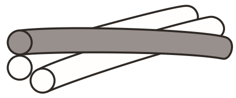


From Rod to Rope **



The Wire

The basic material is wire rod, which is cold-drawn into wire of different diameters and strength grades. The most common grades are:



Rope grade		Wire tensile strength grades				Hardness app.	
EN	API 9A	Min		Max		Brinel	Rockwell
		kp/mm²	N/mm²	kp/mm²	N/mm²	HB	HRC
1570	PS	140	1370	180	1770	405/425	45
1770	IPS	160	1570	200	1960	445/470	49
1960	EIPS (XIP)	180	1770	220	2160	470/480	51
2160	EEIPS (XXIP)	200	1960	220	2160	480/500	52

Finish
The wire is either untreated (bright), galvanised or stainless. Galvanised wire gives the rope greater protection for corrosive environments. For extreme cases a stainless rope is used. Steel wire ropes can also be provided with plastic impregnation.

The Strand

The strand is built up by individual wires which are laid around the core in one or more layers, typically to one of the following constructions:

Ordinary:
Ordinary lay wires - all wires are in the same size.

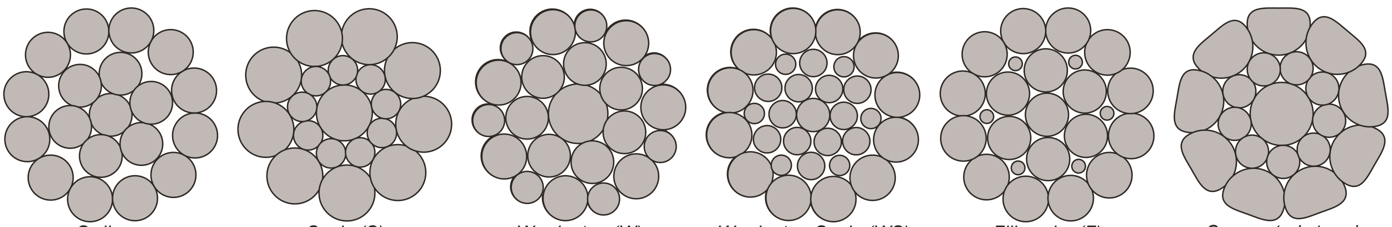
Seale (S):
Parallel lay wires - different size, same number of wires in outer and inner layer.

Warrington (W):
Parallel lay wires - the outer layer of wires has two different sizes, twice as many outer wires as inner wires.

Warrington-Seale (WS):
Parallel lay wires - a combination between Seale and Warrington, with three or more layers of wire.

Filler wire (F):
Parallel lay wires - twice as many outer wires as inner wires, with small wires to fill the spaces between the large wires.

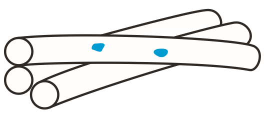
Compacted strand:
A strand that has been formed through compaction maintaining the steel area whilst increasing the fill factor.



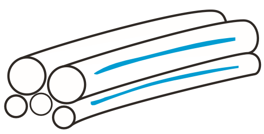
Ordinary *Seale (S)* *Warrington (W)* *Warrington-Seale (WS)* *Filler wire (F)* *Compacted strand*

Strand Lay

In a strand construction with several layers of wire of the same diameter the different layers cross each other (cross lay). In an strand construction with unequal wire diameters the layers of wires lie parallel to each other (equal or parellel lay).



Cross lay



Parallel lay

In equal laid strands the steel area increases compared to cross lay strands. Other advantages of parallel laid strands are the improved fatigue and wear resistance resulting from the same wire lay length and strand angle.

The Core

The strands in a rope are laid around a core of either fibre, steel or solid plastic.

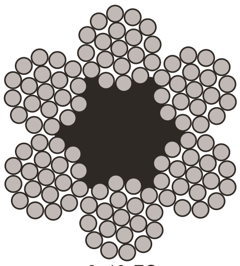
Where the strands are laid over a fibre core FC is used, e.g. **6x19-FC.**

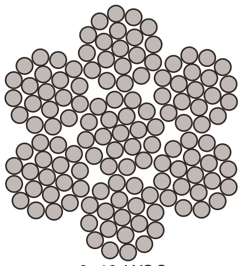
Ropes with steel cores should be chosen if the rope is exposed to high working temperature, hard strains, high work rate, hard pressures on drums and blocks etc. The steel core gives better support for the strands, which result in the rope retaining its shape better and giving a better distribution of the stresses in the individual wires.

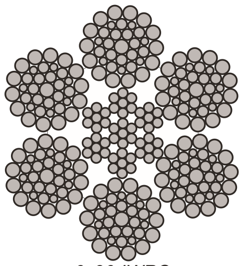
If the steel core of the rope consists of a single strand the term -WSC is used, e.g. **6x19-WSC.**

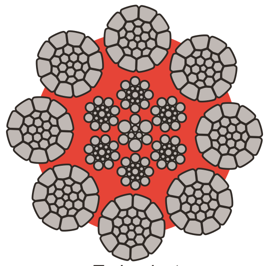
If the steel core of the rope consists of a steel wire rope the term -IWRC is used, e.g. **6x19-IWRC.**

Some steel wire ropes can have a plastic encapsulated core which provides increased stability to the rope and also reduces the wear and corrosion in and around the core, e.g. **Dyform 8 PI.**


6x19-FC


6x19-WSC


6x36-IWRC


Turboplast

Rope Lay

Ordinary hand lay

The direction of the lay of the outer layer of wires in the strands is opposite to the direction of lay of the strands in the rope. Ordinary lay is more resistant to kinking and untwisting, and less likely to fail as a result of crushing and distortion.

Lang's lay

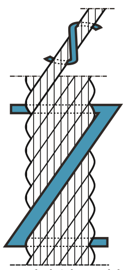
The direction of lay of the outer layer of wires in the strands are in the same direction of lay of the strands in the rope. The advantage of using Lang's lay is that the rope offers a better wearing surface when in use, and therefore can be expected, in many cases to last longer. Lang's lay ropes produce relatively high torque values under working conditions and must not be used on applications where one end of the rope is free to rotate or where problems from rope turn are likely to occur.

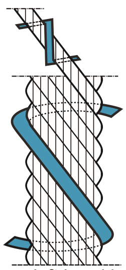
Right hand lay

The strands are twisted to the right around the core. Right hand lay is the most common lay direction in a rope.

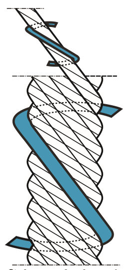
Left hand lay

The strands are twisted to the left around the core.


Ordinary right hand lay (sZ)

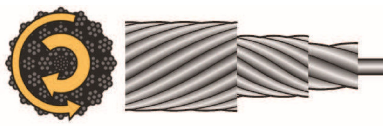

Ordinary left hand lay (zS)


Right Lang's lay (zZ)


Left Lang's lay (sS)

Rotation Resistance

To minimise the tendency to rotate especially with high lifting heights "rotation resistant" or "Low Rotation" ropes should be used.



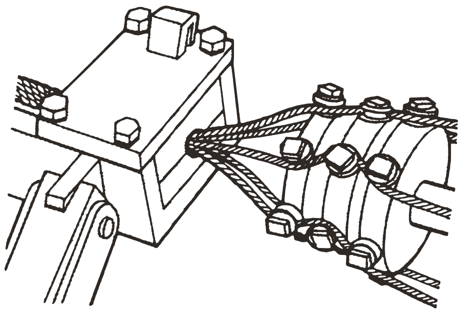
Rotation resistant ropes are made out of many layers of strands. Every layer is laid in the opposite direction to the next layer, so that the torque in the different layers balances the opposing forces in the rope.

Preforming

Preforming is a process that puts a helix in the strands to match the helical shape it will assume in the finished rope. Advantages of preforming include:

– The ropes are free from liveliness and twisting tendencies allowing easier installation and handling.
– The ropes can be cut with minimal seizing as exposed ends will not untwist.

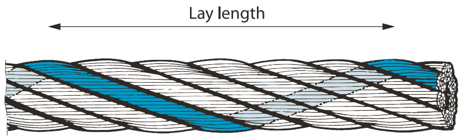
Preforming takes place in a preformhead where the strand pass immediately before the closing operation.



Preforming

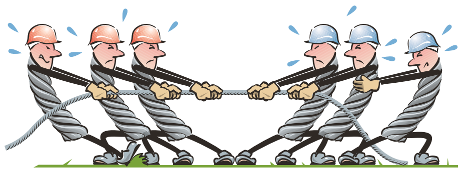
Lay Length

Lay length is the term used for the length of a "wire- or strand helix". Lay length is determined for each wire rope construction and has to be retained, otherwise the life of the wire rope is considerably reduced.



Definitions of Breaking Load

Minimum breaking load
The Minimum breaking force (minimum breaking load), in kilonewtons, is the lowest breaking strain of the rope when tested to destruction.

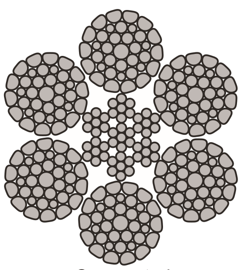


Calculated breaking load
The value calculated from the product of the sum of the crossectional metallic areas of all the individual wires in the rope and the tensile strength grade(s) of the wires. The total metallic area is directly proportional to the square of the nominal diameter of the rope. A standard spinning loss factor that results from the twisting of strands and wire is then applied.

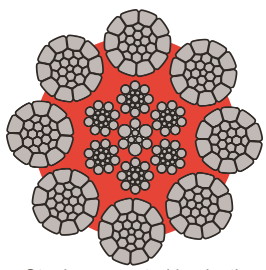
Special Wire Ropes

Demands for longer operation life and higher breaking loads have contributed to the development of "special wire ropes". These are to be used in demanding and tough environments when the ropes are used intensively.
The special wire ropes are often manufactured with high tensile wires and the strands are in many cases **compacted** to give a larger steel area and consequently a higher breaking load. This results in an increased working load for a specific rope diameter. **Compacting** of the rope also results in longer life and therefore a lower life cost.

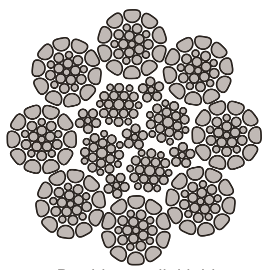
Some areas of use demand wire ropes with better stability and extra low inner friction. For that purpose ropes are manufactured with a plastic coated steel core.
Special wire ropes can be **double parallel** which means that both wires and strands lay parallel to each other. This prevents wire cross over which can lead to wire indentations. Special wire ropes have a few things in common: less outer and inner friction, narrow tolerances, more flexible, more rounded and a larger contact surface against sheaves and drums. This results in a longer life in tough working conditions.



Compacted



Steel core coated in plastic



Double parallel laid

Properties of Extension of Steel Wire Ropes

Any assembly of wires spun into a helical formation (either as a strand or a wire rope), when subjected to a tensile load, can extend in three seperate phases, depending on the magnitude of the applied load:

Phase 1: initial extension
Phase 2: elastic extension
Phase 3: permanent extension (thermal elongation and contraction, rotation, wear and corrosion)

Phase 1 and 2 are very important because they are a normal part of the rope bedding in and working of the rope. Phase 3, on the other hand, can be caused by the wrong choice of rope or lack of rope inspection. The phases occure in sequence in all ropes that are exposed to a gradual increased load. Due to this a new rope, when overloaded, will go through phase 1 and 2 before the third phase (permanent extension) begins.

Phase 1: Initial or permanent extension
This phase of extension of the rope depends on the construction of the rope and can be explained as follows:

When loading a new product, extension is created by the bedding down of the assembled wires with a corresponding reduction in overall diameter. This reduction in diameter creates an excess length of wire which is accommodated by a lengthening of the helical lay.

When sufficientely large bearing areas have been generated on adjacent wires, to withstand the circumferential compressive loads, this mechanically created extension ceases and the extension in phase 2 commences.

The initial extention can not be accurately determined and depends on, apart from the strand or the rope construction, the various loads and the current load frequency.

It is not possible to quote any exact values for various constructions but the following approximate values can be used to give reasonably accurate results.

Load	Safety factor	Extension in % of the total length of the rope	
		Rope with fibre core	Rope with steel core
Lightly loaded	8	0,25	0,125
Normally loaded	5	0,5	0,25
Heavily loaded	3	0,75	0,5
Heavily loaded with many "bends"	2	Up to 2	Up to 1

Phase 2: Elastic extension (elongation)
Following Phase 1, the rope extends in a manner which complies approximately with Hookes Law, i.e. stress is proportional to strain.

The proportionality factor normally is a material constant called Modulus of Elasticity (E-modulus). To steel wire ropes the E-modulus is more of a construction constant than a material constant.

The elastic extension can be calculated as follows (Hookes law):

Elastic extension (mm) = (W x L) / (E x A)

W = applied load (kg)
L = rope length (mm)
E = elastic modulus (kg/mm^2)
A = area of rope - circumscribed circle (mm^2)

The modulus of elasticity varies with different rope constructions. Due to specific manufacturing factors, wire dimensions and other factors, the E-modulus varies between different wire ropes of the same construction and dimension. If the exact E-modulus value of a certain rope is necessary a specific modulus test needs to be done for that rope.

The elastic extension is valid until the proportionality or elasticity limit is reached. Once the load exceeds this limit , extension according to phase 3 takes place. The elasticity limit is defined as the largest force where the rope returns to its original length when unloaded.

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General E-module of the rope construction

Type of steel wire rope	E-module kp/mm²
Spiral strand, type 1x7	12600
Spiral strand, type COMPACTED 1x7	14000
Spiral strand, type 1x19	10900
Spiral strand, type COMPACTED 1x19	13600
6-part single constructions with fibre core, e.g. 6x7-FC	6300
6-part single constructions with steel core, e.g. 6x7-WRC	7000
6-part assemblies with fibre core, e.g. 6x36-FC	5000
6-part assemblies with steel core, e.g. 6x36-IWRC	6000
Compacted constructions with steel core, e.g. ROPETEX 6	6400
Compacted constructions with steel core, e.g. DSC- DYFORM	7900
Multi strand, rotation resistant constructions, e.g. 18x7	4200
Multi strand, rotating resistant constructions, e.g. 35x7	6900
Multi strand, rotating resistant compacted constructions, e.g. RopeTex 88	7200
Elevator rope TRULIFT 8F (8x19S-FC)	4000
Elevator rope TRULIFT 8SPC (8x19S-SPC)	4300

Type of steel wire rope	E-module kp/mm²
Elevator rope TRULIFT 8S (8x19S-IWRC)/TRULIFT 9S (9x19S-IWRC)	6000

These values are valid for ropes operating with a safety factor of 5:1. With lower safety factors the modulus of elasticity indicated are increased and for higher safety factors they reduce.

Phase 3: Permanent extension

The permanent, non-elastic extension of the steel caused by tensile loads exceeding the yield point of the material. If the load exceeds the Limit of Proportionality, the rate of extension will accelerate as the load is increased, until a loading is reached at which continuous extension will commence, causing the wire rope to fracture without any further increase of load.

Thermal Expansion and Contraction

The coefficient of linear expansion (□) of steel wire rope is 0.0000125 = (12.5 x10-6) per ° C and therefore the change in length of 1 metre of rope produced by a temperature change of t ° C would be;
Change in length Δ| = □ |o t
where:
□ = coefficient of linear expansion
|o = original length of rope (m)
t = temperature change (° C)
The change will be an increase in length if the temperature rises and a decrease in length if the temperature falls.

Extension due to Rotation

The elongation caused by a free rope end being allowed to rotate.

Extension due to Wear

The elongation due to inter-wire wear which reduces the cross-sectional area of steel and produces extra constructional extension.

Example:

The total elongation of a 200 m length of steel wire rope type 28 mm 265-wires (6x36-IWRC) at a tension of 10 tonnes (safety factor 5:1) and with an increase in temperature of 20°C.

According to phase 1:
Permanent constructional extension = 0,25% x total rope length = 0,25% x 200 m = **500 mm**.

According to phase 2:
Elastic extension = (W x L) / (E x A) = (10000 x 200000) / (6000 x 615,4) = **540 mm**.

According to phase 3:
Thermal expansion = 0,0000125 x L x t = 0,0000125 x 200 x 20 = **50 mm**.

Total extension = 500 mm + 540 mm + 5+ mm = **1090 mm**.

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Temperature Affect on Working Load Limit (WLL)

Account should be taken of the maximum temperature that can be reached by the wire rope sling in service. This is difficult in practice but underestimation of the temperature should be avoided.
The table below summarises the necessary de-rated working load limits of a sling due to temperature, taking into account the type of rope termination, the ferrule material and the core of the rope.

When wire rope slings are to be used in temperatures below -40 °C CERTEX should be consulted.

The use of wire rope slings within the permissible temperature ranges given in the table does not require any
permanent reduction in working load limit when the rope is returned to ambient temperature.

Termination type	Ferrule-material	Rope core	De-rated working load limit expressed as % of WLL of the sling Temperature (t) °C					
			-40 - 100	101 - 150	151 - 200	201 - 300	301 - 400	400<t
Ferrule	Aluminium	Fibre	100	Do not use	Do not use	Do not use	Do not use	Do not use
Ferrule	Aluminium	Steel	100	100	Do not use	Do not use	Do not use	Do not use
Ferrule	Steel	Fibre	100	Do not use	Do not use	Do not use	Do not use	Do not use
Ferrule	Steel	Steel	100	100	90	75	65	Do not use
Splice	-	Fibre	100	Do not use	Do not use	Do not use	Do not use	Do not use
Splice	-	Steel	100	100	90	75	65	Do not use
Socket	zinc/alloy	Fibre	-40 - 80ºC 100%					
Socket	zinc/alloy	Steel	-40 - 120ºC 100%					
Socket	2-component	Fibre	-50 - 80ºC 100%					
Socket	2-component	Steel	-50 - 80ºC 100%					

CERTEX should be consulted in case the slings are to be exposed to chemicals combined with high temperature.
Wire rope slings should not be used either immersed in acidic solutions or exposed to acid fumes.

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Use and maintenance

Drum - Correct Coiling

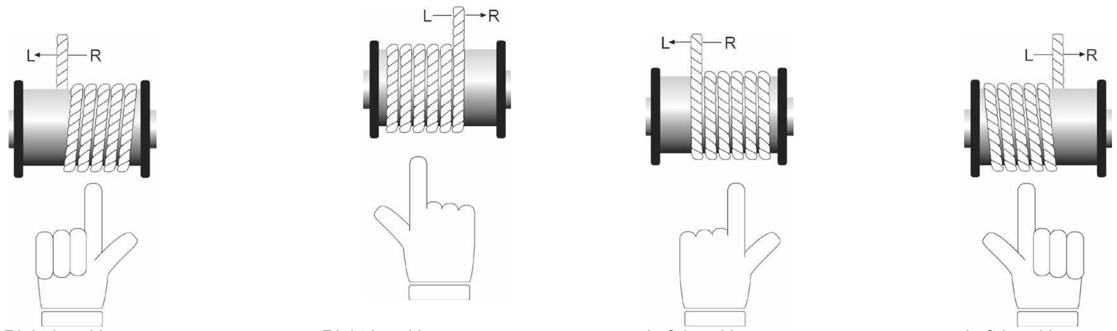
The rotation direction and the attachment point of the rope determines whether right or left hand lay rope should be used. To determine the correct rope the following rule should be followed:

Right thread groove on the drum - left hand lay rope.
Left thread groove on the drum - right hand lay rope.

Warning! Incorrect choice of lay can adversely affect rope performance.

Pass a shaft through the reel and place the reel in a suitable stand which allows it to rotate and be braked to avoid over run during installation. Where multi-layer coiling is involved it may be necessary for the reel to be placed in equipment which has the capability of providing a back tension to the rope as it is being transferred from reel to drum. This is to ensure that the underlaying (and subsequent) laps are wound tightly on the drum.

Warning! Incorrect coiling may cause severe damage to the wire rope as well as its performance.

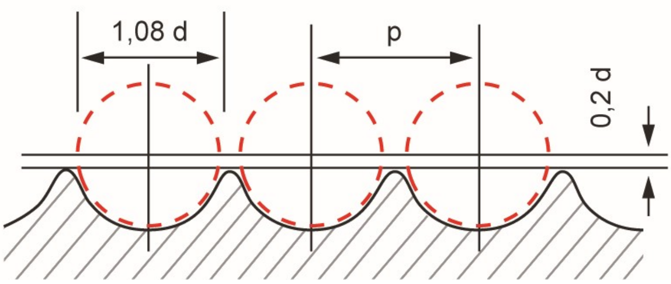


Right hand lay rope From right to left | *Right hand lay rope From left to right* | *Left hand lay rope From right to left* | *Left hand lay rope From left to right*

Drum - Groove

Check the general condition of the drum. If the drum is grooved, check the radius and pitch are compatible with the diameter of the new rope.

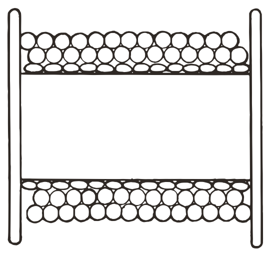
Warning! The drum can in some cases cause damage to the rope and lead to early discard. If the drum diameter is too small this can cause permanent distortion to the rope which will cause to early discard of the rope.



d	p
- 10	1,15 d
10 - 20	1,12 d
20 - +	1,10 d

Drum - Multiple Layers

Multiple layers of wire on the drum can cause deformation (flattening, distortion etc) in the lower layers if the wrong rope construction is used and/or by incorrect winding.



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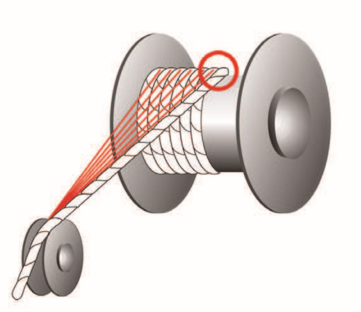
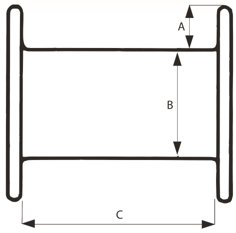
Drum - Fleet Angle

Too large a fleet angle can cause excessive wear of the rope against the adjacent wrap on the drum. This can also lead to torsional problems.



Drum - Capacity



The following formula gives an approximate indication of the length of a rope of a given diameter (d), which can be installed onto a drum.

Rope length (m) = $(A+B) \times A \times C \times \pi \times 10^6 / d^2$

A, B and C are quoted in metres and d in millimetres.

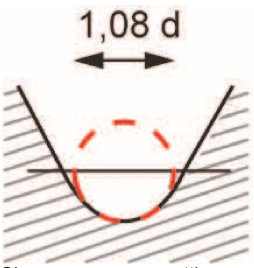
Note that ropes are normally manufactured to a maximum oversize tolerance of up to 5%.

Sheaves

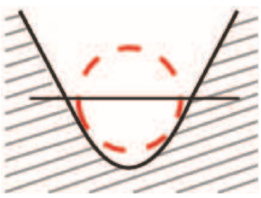
Before installing a new rope the sheave grooves, layers and lubrication should be checked.

Measure the groove diameter with a radius gauge and check the general condition of the groove. Groove diameter shall be nominal rope diameter +8% to +14% (0,54 x d to 0,57 x d).

Warning! Worn sheaves should be replaced/refurbished.

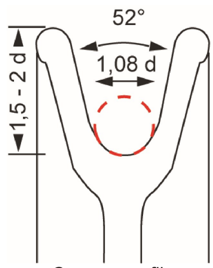


Sheave groove correctthe rope has maximal contact surface.



Sheave groove too narrow- wires and strands in the rope deformed, which means short life of the rope.

Sheave groove too widerope has bad support, risk for de-form of the rope and damages in the groove profile.



Groove_profile

Maintenance - Lubrication

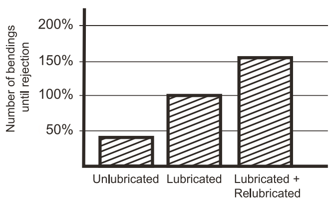
When a wire rope is in operation the individual wires rub against each other. To reduce the friction the rope is lubricated during manufacture. The lubrication improves the performance of the rope and increases its life.

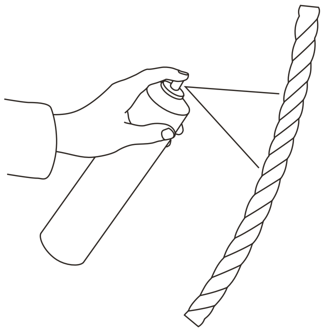
Check the lubrication of the rope immediately after installation and clean the rope from inappropriate material, for example sand and dirt, periodically the rope should also be lubricated before use.

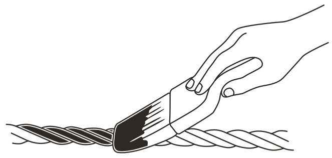
It is also important that lubrication is made in intervals of time depending on operating conditions and intensity of use.

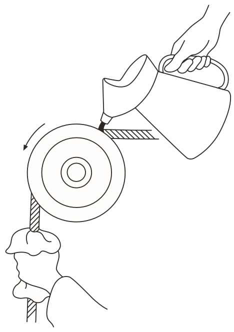
WARNING! An unlubricated or incorrectly lubricated rope has a significantly reduced life.

Contact CERTEX for further advice and help on lubrication.









Examination

During examination of steel wire ropes attention should be made specifically to the parts of the rope that are, known from experience, to be exposed to wear and damage.

Wear, broken wires, distortion and corrosion are the most common visible signs of deterioration.

Wear is a normal feature of rope service and the correct rope construction ensures that it remains a secondary aspect of deterioration. Correct lubrication of the rope may help to reduce both outer and inner wear.

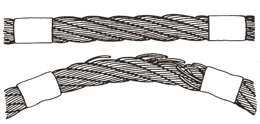
Broken wires are normal features of rope service towards the end of the rope's life, resulting from bending fatigue and wear. The local break up of wires may indicate some mechanical fault in the equipment. Correct lubrication in service will increase fatigue performance.

Individual broken wires shall be attended to by removing the wire, see figure.

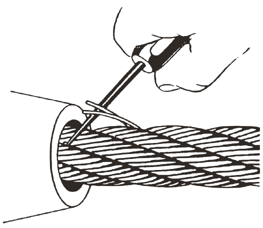
Distortions are usually as a result of mechanical damage, and if severe, can considerably affect rope strength.

Corrosion, both outer and inner, indicate unsuitable grease. Pitting on the external wire surface can result in broken wires. Inner corrosion occurs in some environments when lubrication is inadequate or of a unsuitable type. A reduction in rope diameter will frequently indicate this condition, but confirmation can only be made by an internal examination of the rope.

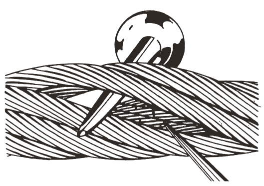
WARNING! Do not cut the wire, bend it until it breaks close to the inside of the strajd. This reduces the risk of the ends of wires sticking out of the rope.



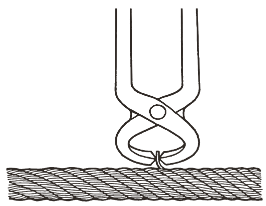
Inspection



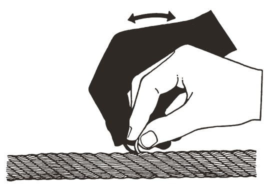
Inspection



Inspection



How to remove broken wires
Wrong

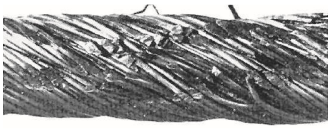


How to remove broken wires
Right

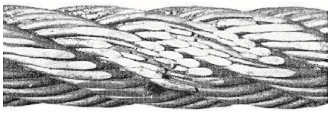
Rope discard

Discard the wire rope in accordance with current regulations or according to the manufacturers recommendations.
Only a qualified and experienced person should be responsible for discard.
The pictures show typical examples of wire rope deterioration.

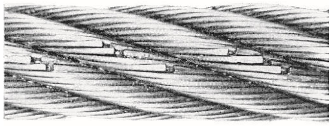
Warning! Failure to take adequate precautions could result in injury.



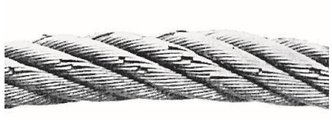
1. Mechanical damage due to rope movement over sharp edge projection whilist under load.



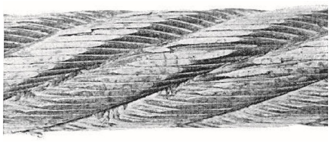
2. Localised wear due to abrasion on supporting structure. Vibration of rope between drum and jib head sheave.



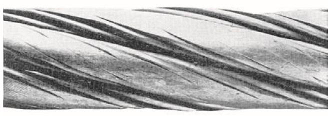
3. Narrow path of wear resulting in fatigue fractures, caused by working in a grossly oversize groove, or over small support rollers.



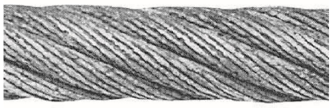
4. Two parallel paths of broken wires indicative of bending through an undersize groove in the sheave.



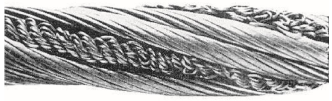
5. Severe wear, associated with high tread pressure. Protrusion of fribre main core.



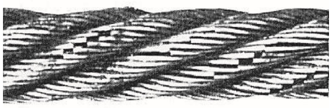
6. Severe wear in Langs Lay, caused by abrasion at cross-over points on mulit-layer coiling application.



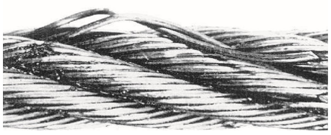
7. Corrosion of severe degree caused by immersion of rope in chemically treated water



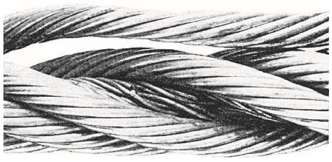
8. Portrusion of steel core resulting from shock loading.



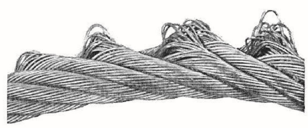
9. Typical wire fractures as a result of bend fatigue.



10. Wire fractures at the strand, or core interface, as distict from "crown" fractures, caused by failure of core support.

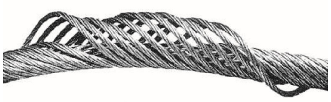


11. Break up of the steel core resulting from higt stress application. Note nicking of wires in outer strands.

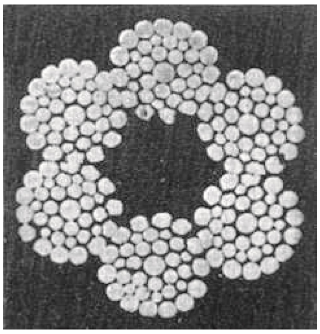


12. Strand core protrusion as a result of torsional unbalance created by "drop ball" application (i.e. shock loading).

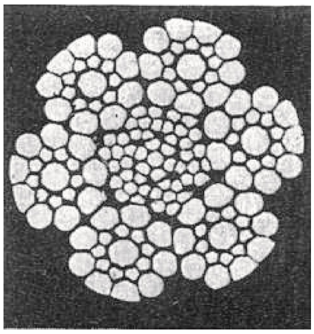
13. Typical exampel of localised wear and deformation created at a previously kinked portion of rope.



14. Multi strand rope "bird caged" due to torsional unbalance. Typical of build up seen at anchorage end of multifall crane application.



15. Internal corrosion prominent while external surface shows little evidence of deterioration. Complete lack of strand gap suggests internal degradation.



16. Substantial wear and severe internal corrosion. High tension abrasion and corrosive environment are combined in this example.