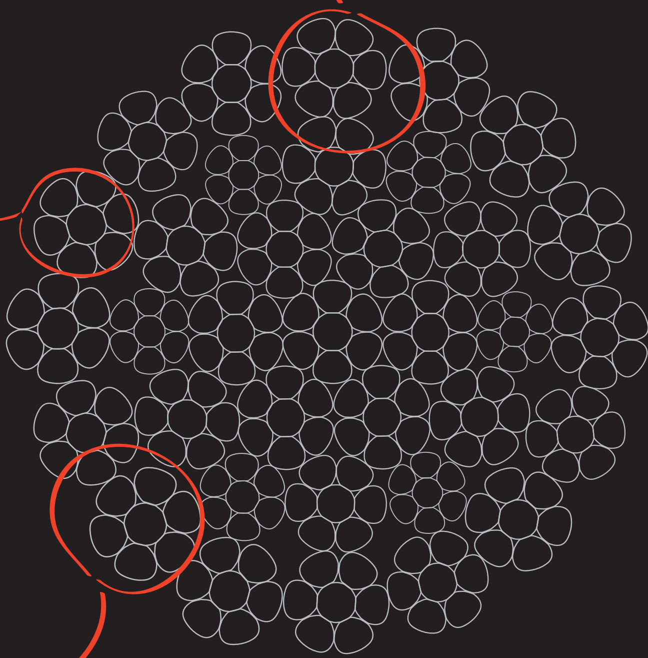
usha martin

Wire Rope
User Manual

Company Profile

Brunton Shaw and Usha Martin Italia, Usha Martin Group Companies

Brunton Shaw UK is a successful manufacturer of high quality wire ropes for a wide range of applications, which effectively combines more than 100 years of experience and tradition with an up to the minute range of products, and a customer service package ideal for the modern market place.



Usha Martin Group, started in 1961 in Ranchi as a wire rope manufacturing company, today is a USD 1 billion conglomerate with a global presence. With continuous growth in both the domestic and international markets, Usha Martin has emerged as India's largest and the world's second largest steel wire rope manufacturer.

UMI - Usha Martin Italia SpA is the last born of the Group. It has been settled in January 2013 to support all Usha subsidiaries,
incorporating a highly qualified engineering office focused to computer aided rope design and application engineering and a specialized laboratory for rope inspection and R&D activities.

List of topics

Preface about rope use

A wire rope can be simply considered as an assembly of several strands laid helically in different possible arrangements in order to bear axial loads. To be fit for purpose, it must also ensure other features, like resistance to side loads, flexibility, handling and stability. This definition, however, does not cover completely the implications of correct rope design, manufacturing, use and inspection, as the real mandatory requirement must be, in any case, safety compliance, which allows adequate working conditions for men and environment.
To ensure high quality standards, our Company has settled up a complete process, which includes custom design software, state of the art manufacturing equipment and skilled personnel with proven expertise.
Rope integrity management should always be operated by properly trained personnel, who should always refer to general regulations, specific customer standards, local legislation and internal guidance.
The content of this document is a brief abstract of rope characteristics and recommendations for rope use and it is not intended to be all-inclusive; specific matters can be followed with special care to customer needs by our technical departments.

Rope diameter and measurement

Each rope is first of all characterized by the nominal diameter and oversize, which have to be selected depending on system configuration and reference regulations.
According to EN12385-1, ISO and API standard, diameter measurement has to be taken on a straight portion of the rope, either under no tension or a tension not exceeding 5% of the minimum breaking force, at two positions spaced at least one metre apart. At each position two measurements, at right angles, of the circumscribed circle diameter shall be taken.
The most suitable measuring equipment is plate gauge, capable to cover at least two strands (see Figure 1).

Figure 1 Diameter measurement

Diameter must be measured and recorded immediately after rope receipt, as this value has to be used as a baseline for following inspections.
It has always to be considered that the actual diameter of the rope changes during use due to initial stabilization, to the effect of working tension and to wear generated by the passage over the components of the reeving.
Permanent diameter reduction after first pull can vary from 0.5% to 3% depending on rope and core construction.
Diameter measurement is an essential tool which allows to give an immediate and simple evaluation of the overall condition of the rope.
For example, a localized diameter variation can indicate undesired phenomena like geometrical deformation, core distortion or presence of heavy corrosion, while a distributed diameter reduction can be associated to wear due to intensive use. Ovalization is also a marker of possible rope issues which have to be properly addressed.

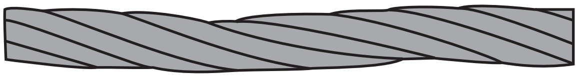


Figure 2 Sunken strand and associated diameter reduction

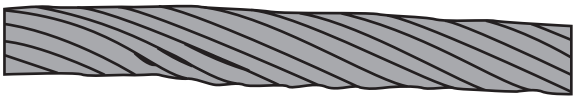


Figure 3 Core distortion and associated diameter increase

Rope lay measurement and selection

Lay length represents one of the key characteristics of the rope and affect its elasticity and performance under load. It has to be periodically measured, as possible variations can indicate rope issues, like forced rotation during installation, or unlay due to excessive lifting height, or misalignment of the reeving components.

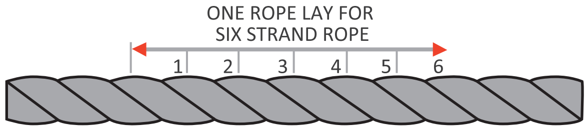


Figure 4 Lay length measurement for a six strand rope

The choice of a Lang or regular lay rope has to be based on rope use and desired performance.
Lang lay ropes (i.e. ropes having same direction as the outer strands) give better stability to side wear (phenomenon also known as "crushing") as the contacts between the wires of adjacent rope wraps are smoother. They are particularly indicated up to 40 mm size ropes used on deck cranes or small winches.
Regular lay ropes (i.e. ropes having opposite direction in respect of the outer strands) ensure improved rotation stability and are therefore recommended for relevant lifting height or high capacity cranes.

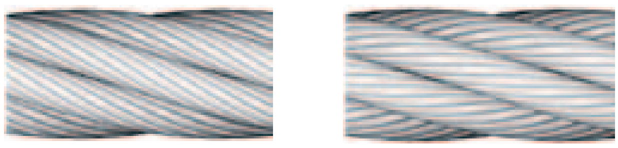


Figure 5 Lang lay (left figure) and regular lay (right figure)

The natural tendency of the rope to twist must be in accordance with the direction of drum winding to get a tight contact between adjacent wraps, especially on the first layer.
In case of plain drum, right hand or left hand lay direction must be selected in order to match the drum's type and direction, as shown the figure.
These indications are not strictly required for grooved drums, as in this case the rope is already guided by the grooves themselves. In case of grooved multilayers drums, lay direction can be selected to facilitate the first layer spooling or optimized considering the rope layer that will be more frequently used during operations.
In case of grooved drums, an adequate number of safety wraps should remain in place to avoid rope slipping, while in case of plain drum the whole first layer should never be used, as it works as a bedding for the following layers.
Painting the first layer or the safety wraps is a good practice to clearly detect the use of a forbidden portion of rope.

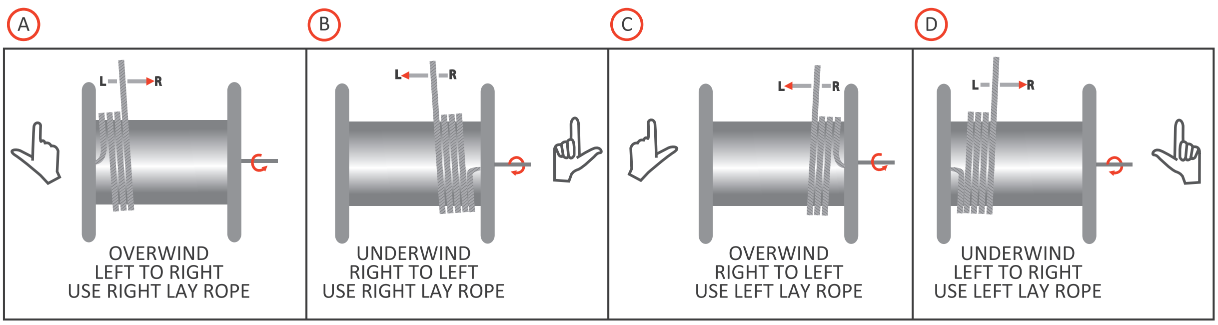


Figure 6 Selection of lay direction

Benefits of compacted strands

Ropes for special applications and heavy lifting activities require a high load efficiency and breaking load, which cannot be achieved using traditional round strands. For this reason, these ropes are typically composed by compacted strands, whose compacting level can be designed and modulated depending on specific requirements. Compacted strands are obtained by the passage through a die or a series of rollers applied on the strander machine just after the closing point, as shown in the figure.

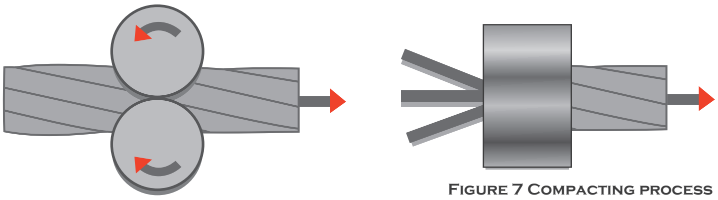


Figure 7 Compacting process through rollers or die

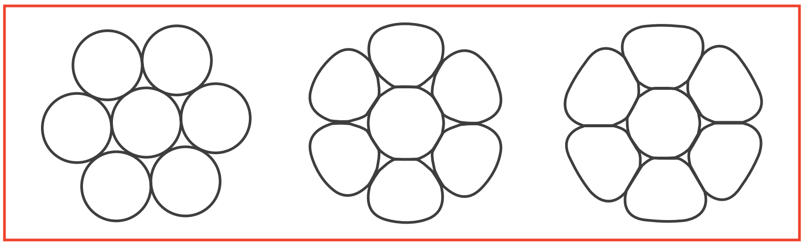


Figure 8 Round strand, light and high compacting level

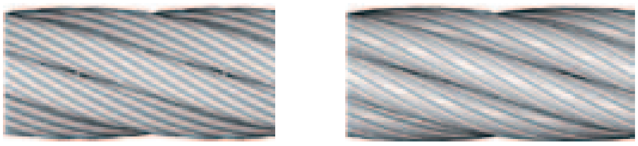


Figure 9 Round strand versus compacted strand

The main benefit of compacted strands adoption is the increase of metallic area in respect to round strands, which allows to get higher breaking force. This process also gives higher cooperation level to the individual wires, homogeneous and stable strand diameter, resistance to side pressure, wear and abrasion.
Finally, smoother contact surface between the strands and rounder profile gives better spooling performance and resistance to crushing.

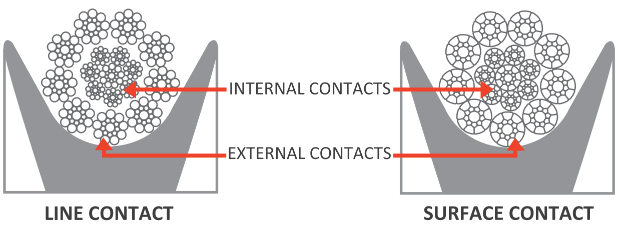


Figure 10 Contact surfaces for a non compacted and a compacted rope

Fleet angle and plastic impregnated core ropes

Rope routing must be carefully considered to prevent early damage: one of the most critical factors is the presence of deflection (i.e. fleet) angles between two sheaves or from the drum to the spooler.

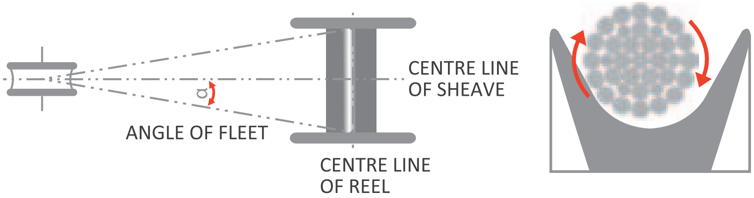


Figure 11 Fleet angle during spooling and rope rolling

When fleet exists, the rope is induced to roll and slide into the groove, causing shortening and increasing of the lay length and possible permanent distortion of the rope structure, like birdcage or core protrusion.

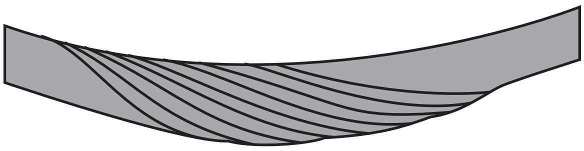


Figure 12 Birdcage deformation

Fleet angle should never exceed 2°, it can be increased up to 4° with the adoption of plastic impregnated core ropes. In this type of ropes, plastic is applied to the core after its closing and is lightly heated and softened before final closing in order to create a connection between outer strands and core strands.
Plastic layer must not work as a cushion (see left sketch), but must ensure radial stiffness and diameter stability and therefore maintain the steel over steel contact between the strands (see right sketch).

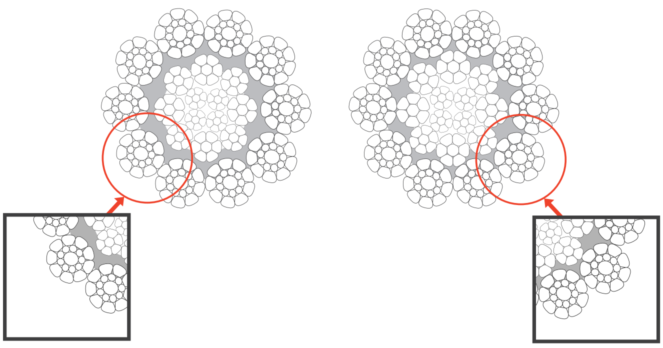


Figure 13 Cushion layer versus plastic impregnated core

Rotational characteristics and use of swivel

Being composed by helically laid elements, each rope has the natural tendency to twist when subjected to axial loads. This depends on the geometrical arrangement and can be reduced by compensating the core tendency to rotate in one direction with an opposite tendency of the outer layer, as typically applied to spin resistant and non rotating ropes.
Rope are conventionally classified based on the number of turns that a portion with length of 1000 times nominal rope diameter would make when pulled at 20% MBF: with less than 1 turn a rope is classified as non rotating, from 1 to 4 turns as low rotation, from 4 to 10 as spin resistant, higher than 10 as not non rotating.
Each rope is characterized by torque factor, which is used in the calculations when both ends of the rope are fixed, and rotation factor (expressed in degrees/lay), which is used when one end is free to rotate.
Both torque factor and rotation factor strongly decrease after rope stabilization and are negligible if the rope is always used at same working load and lifting height.
In case of single fall lifting a non rotating rope is typically recommended, while in case of multi-part reeving arrangement, rope type has to be selected depending on height of lift, block configuration and loading.
A wrong rope selection or improper installation and training can cause cabling phenomenon, which can lead to permanent rope deformation, like waviness, and severe operations issues.
The maximum lifting height for a given rope torque factor "t" can be briefly calculated using the approximate formulas shown in the sketch (all dimensions are in mm). In case of special block arrangement, please contact us for a custom evaluation.
When operating a non rotating rope in single fall mode, a swivel can be used to relieve the rope of any induced rotation resulting from angular deflections at a sheave or drum.
Swivels must not be used with not non rotating ropes, like 6 strand, as it would cause rope unlay, severe reduction of its breaking force and secondary fatigue of the steel core, not detectable during inspections.

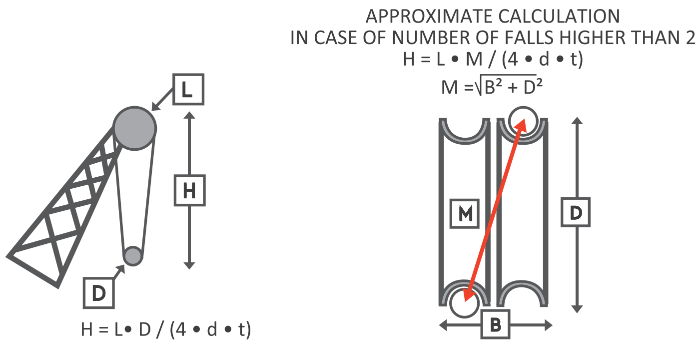


Figure 14 Calculation of maximum lifting height

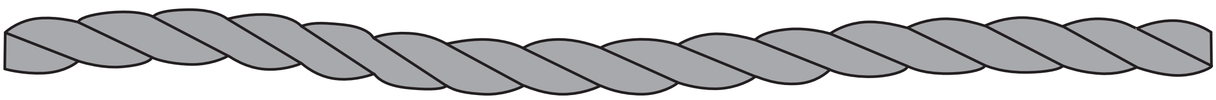


Figure 15 Rope waviness

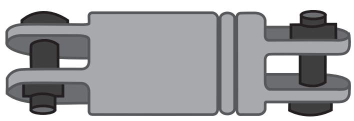


Figure 16 Example of swivel

Reel receipt and storage

After receipt, the rope should be immediately checked to verify its identity and condition and should not be used without the possession of adequate documentation and certificates.
The Certificate of Conformity by the manufacturer should be stored in a safe designated place in order to quickly identify the rope and carry out periodic inspections.
During loading, transferring and unloading operations, rope reels or coils should be properly handled using slings or lifting beams as shown in the figures below.
Slings must have an adequate length to avoid flange ends overstress during reel lifting.
The rope should be checked to verify that it is not damaged when unloaded and transported to storage site and should not come into contact with parts of the lifting devices, like hooks and forks.
Some recommendations for rope handling are indicated on specific labels applied on the reels (see figure, with a detail of EWRIS label).

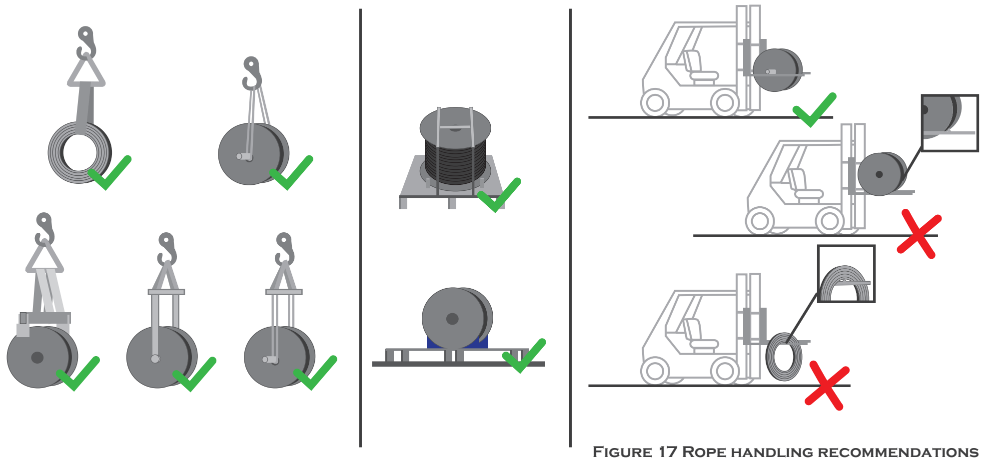


Figure 17 Rope handling recommendations

Storage conditions are essential to prevent rope damage: it should be avoided to keep the rope in very warm or humid environment, as this could break down the effectiveness of native lubrication and accelerate the deterioration process. If lubricant has the tendency to drain due to high temperature, the reel should be periodically rotated to maintain a homogeneous distribution.
The rope should not be stored in places which could be affected by chemical agents, corrosive matters or accidental damages and, if stored outside, the reel should be positioned in order to avoid direct contact with the ground and covered with waterproof material.
The rope marking should be clearly detectable and readable in order to safely and quickly identify the reel.

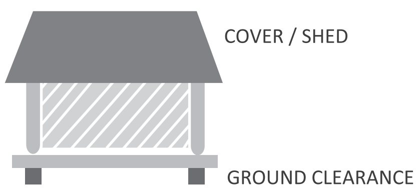


Figure 18 Reel storage

Rope pay out

Ropes can be supplied on coils or reels depending on size and customer requirements.
If the rope is supplied on a coil, it should be placed on the ground and rolled out straight, avoiding contamination with dust, grit, moisture or other harmful material.
The rope should never be pulled away from a stationary coil as this will induce turns into the rope and form kinks (see figure).

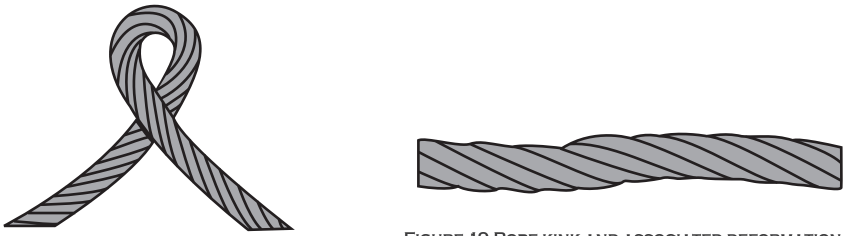


Figure 19 Rope kink and associated deformation

If the coil is too large to be physically handled, it may need to be placed on a turntable to pay it out as the end of the rope is pulled away from the coil.
If the rope is supplied on a reel, a shaft of adequate strength should be passed through the reel bore and the reel should be placed in a suitable stand which allows it to rotate and be braked to avoid overrun during installation.
If a loop forms in the rope it should not be allowed to tighten to form a kink.
The reel stand should be mounted in a way that avoids reverse bend during reeving: for a drum with an underwind rope, take the rope off the bottom of the supply reel.
Underwind is also preferable in respect to overwind, as it gives higher stability to the stand and less risk of overturn.
When releasing the outboard end of the rope from the supply reel or coil, this should be done in a controlled manner.

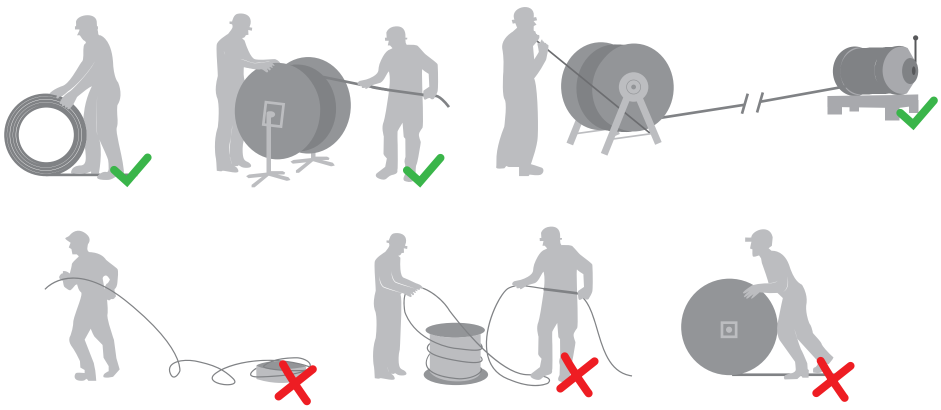


Figure 20 Recommendations for rope pay out

SERVING AND CUTTING

During manufacturing process, the strands can be preformed in order get a helical profile just before closing and improve rope stability and handling. Similar purpose can be achieved through postforming, which consists of the passage of the rope through a series of rollers.
With the exception of very specific applications, preforming and postforming level must be such to stabilize the rope without reaching extreme levels, as this would make the rope very faint during use.
Therefore, unless the rope has been subjected to complete preforming, it will have the tendency to unlay when cut.
For this reason, serving shall be applied before rope cutting to keep strands in position and it has to be performed carefully, as its failure may cause injuries or rope permanent damages.
Serving must be also performed before socketing and in this case it has to allow socket medium penetration between the rope and the socket bore.
The material shall be tinned or galvanized soft wire or strand for zinc/zinc alloy coated wire ropes, and bright, tinned or galvanized soft wire or strand for bright wire ropes.
Wire diameter shall be such to firmly hold the strands and, particularly in case of large size ropes, seven wires strands can be used as an alternative to single wires.
Service length should be at least equal to two rope diameters (see figure).
For preformed ropes one serving is typically enough, while for not preformed ropes, rotation resistant and parallel closed ropes a minimum of two servings is recommended.
Before cutting the rope, a clear mark should be applied on the cut area and servings should be applied at each side of the mark.
Depending on its size, the wire rope can be fused and tapered or cut using high speed abrasive disc cutters, percussive or shearing methods, paying particular attention not to disturb the position of wires and strands below the serving.
Rope core can be cut with no major issues in case the it has the tendency to protrude in respect to the outer layer.

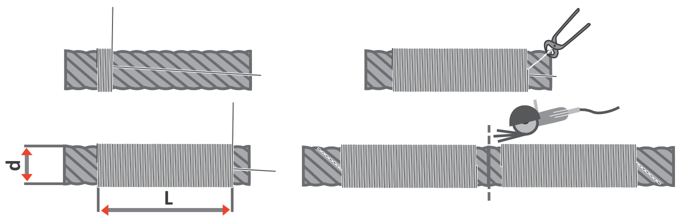


FIGURE 21 SERVING DIMENSIONS AND CONFIGURATION

Rope size	Diameter of service wire or strand [mm]	
	Wire	Strand
Up to 22 mm	1.1 - 1.5	1.6 - 1.8
From 22 to 38 mm	1.4 - 1.8	1.6 - 2.5
From 39 to 76 mm	1.6 - 2.0	2.5 - 3.0
From 77 to 100 mm	1.8 - 2.2	3.0 - 3.5
Over 100 mm	n/a	3.5 - 4.0

TABLE 1 TYPICAL SERVING WIRE AND STRAND DIMENSIONS

Socketing operation

Rope end connections can be temporary, if used for rope rewinding or installation on the drum, or permanent, to be used during lifting operations.
Permanent connections allow to respect the installation safety working load and are characterized by a specific efficiency depending on the connection type, which varies from 100% for resin sockets to 80% for wedge sockets.
Temporary end connections must not be used as lifting devices, as they are not designed to ensure safety working load but only to allow to move the rope from the storage reel to another reel or to the winch drum.
Socketing media can be metal or resin, which is more extensively used due to ease of handling and safety. Moreover, heat generated during metal socketing can affect steel properties of the rope.
According to regulations (i.e. EN12927), the length of the tapered part of a socket shall be at least 5 times the nominal rope diameter or 50 times the outer wire diameter and the angle between the generatrix and the axis of the cone shall be from 5° to 9°.The socket basket neck diameter shall be from 1,2 up to 1,3 times the rope nominal diameter and shall have a cylindrical portion long from 0,25 up to 0,5 times the rope nominal diameter.
The internal socket profile must not have grooves, as these would reduce resin penetration.
To perform proper socketing, the position of the wires and strands of the non-socketed portion of rope shall remain undisturbed during the socketing operation, therefore adequate servings are required.
Dirt, grease, scale or residues shall be removed from the inside of the socket basket to prevent resin contamination.
After having inserted the rope into the socket, all the individual wires shall be opened to form a brush, which shall be degreased to remove all traces of lubricant and shall be completely dry before the socketing medium is poured into the socket. Wire shall not be straightened when forming the brush, as this would reduce the efficiency of the socketing media.

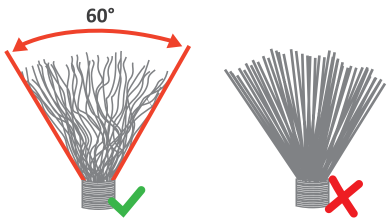


Figure 22 Socket brush

$$C = \frac{\pi \cdot H \cdot (D+d)^2}{4}$$

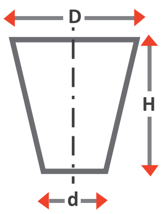


Figure 23 Resin content and cone dimensions

The wires shall be evenly distributed around the circumference within the socket basket and the area where the rope enters the bore of the socket shall be sealed with a material that prevents leakage of resin and that shall be removed after socketing. Before starting the operation, the socket must be aligned with the rope axis.
The operator shall follow the resin manufacturer's instructions, resin system packages or kits shall not be sub-divided or used after the expiry date indicated on the container or out the prescribed temperature range.
The socket shall be filled from a single pour until the basket is full: the approximate resincontent in cc for a standard spelter socket can be calculated using the formula in the sketch (cone dimensions are in cm).

During the pouring and topping-up operation and early stages of gelling, it is essential that possible leaks are identified and stopped, as such leaks may generate cavities near the neck of the brush.
The resin mixture shall be allowed to harden after gelling and the socket shall not be moved until the resin has hardened. Some resins contain a coloring component which turns to blue during gelling.
Wire protruding after hardening due to resin loss of volume helps to verify the proper wires distribution into the cone and does not need to be covered or removed.

Inspection of grooves and sheaves

Before installing the new rope, the condition and dimensions of interface parts, like drums, sheaves and rope guards, should be checked to verify that they are within the operating limits as specified by the original equipment manufacturer.
The groove diameter, which can vary from 5% to 10% above the nominal rope diameter, should be checked using a sheave gauge (see figure). Sheaves should also be checked to ensure that they are free to rotate.

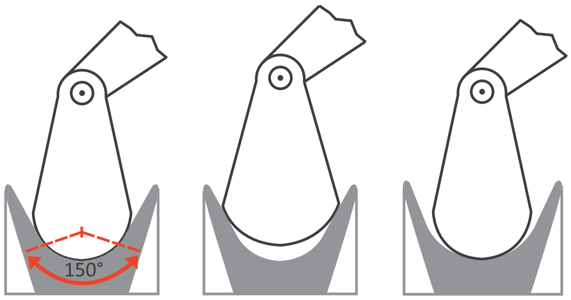


FIGURE 24 GROOVES INSPECTION: CORRECT SIZE, NARROW AND LARGE GROOVE

Grooves material and hardness is also important for good system performance: the typical recommendation is to use hardened steel (minimum 300HB) which ensures good pressure resistance between the rope and the sheave. When grooves become excessively worn, they can be re-machined if sufficient wall thickness will remain in the underlying material after the machining has been carried out.
Improper groove finishing can generate irregular rope routing and derailing over the sheave (see figure).

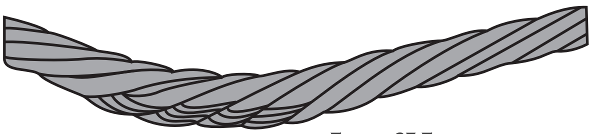
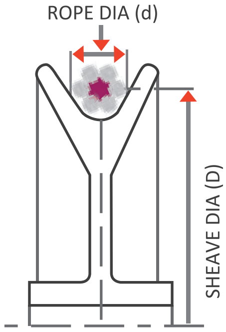


FIGURE 25 FLATTENED PORTION DUE TO ROPE DERAILING

The recommended bending ratio D/d (e.g. ratio between diameter of the component and rope nominal diameter) depends on rope construction. Some typical values for crane applications are shown in the following table and are determined based on uniform stress distribution of rope, strands and individual wires.
Other values can be found on specific regulations.



Construction	Suggested D/d ratio
6 x 46, 8 x 36	18
19 x 19, 35 x 7, 6 x 41, 8 x 25	20
6 x 36	23
8 x 19, 6 x 25, 6 x 31	26
19 x 7, 6 x 19	34

TABLE 2 EXAMPLES OF RECOMMENDED BENDING RATIOS FOR CRANES

ROPE INSTALLATION AND TRAINING

Rope spooling and installation should be carried out in accordance with a detailed plan issued by the user of the rope to prevent safety hazards and early rope damage.
The installation tension should be at least the highest value between 2% of the rope MBF or 10% of rope SWL.
This tension can be obtained directly using the spooling device or later during training stage, depending on rope size and equipment availability.
Standard rope reels are designed for transportation and storage, therefore they can bear a limited amount of pulling tension, which is approximately 3 times the reel diameter for steel reels, 0.5 times the reel diameter for wood reels (e.g. 1.5 meter steel reel can bear up to 4.5 tons, 1.5 meter wood reel can bear un to 0.75 tons) up to a maximum of 10 tons using four spindles. If higher tension has to be applied, the rope has to be spooled on an intermediate reel or special reel requirements have to be agreed with the rope supplier.
When first installing the rope, a pilot line having adequate breaking force to bear the installation pull should be reeved on the system and connected to the rope itself.
The pilot line shall have same lay direction and type as the rope to be installed, otherwise twist could be induced and permanent damage could occur.
It the rope is superseding an existing one having same characteristics, it can be installed with the aid of the old one by connecting the two wire ends in a proper way using clamps, splice, chinese finger, becket loop, etc.
A swivel should not be used during the installation of the rope.
During pulling into the system, the rope should be carefully monitored and it should not obstructed by any part of the structure that may bring damage and result in a loss of control.

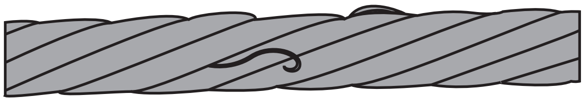


FIGURE 26 BROKEN WIRE DUE TO IMPROPER HANDLING

The equipment should be run at limited speed to facilitate gradual rope stabilization. Full load should never be applied during this stage.
During spooling, continuous check has to be performed to verify that no slack occurs in the rope or cross-laps of rope develop at the drum, as irregular coiling would inevitably result in severe surface wear and rope distortion.
In multilayer drums, the crossover area (see figure) must be carefully monitored.
A good spooling will show tight wraps and uniform rope arrangement also in the cross over zone and up to the last layers, which will reduce the risk of crushing, cut-in or early formation of broken wires.

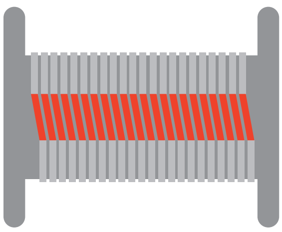


FIGURE 27 CROSSOVER AREA

Training is also essential to stabilize rope dimensions and to optimize rope lifetime and performance.
It is performed by lifting an adequate load for at least three times using the full rope length, excluding the safety wraps which must always remain on the drum: the load automatically generates proper backtension, diameter stabilization and torque factor reduction.

Lifting operations

Applicable regulations give indications to ensure that lifting equipment is safe when new, that it is used safely and that it remains safe for use.
Equipment and accessories are marked with their own safety working loads and must never be used out of the prescribed interval. They should always be thoroughly examined according to examinations schemes and timing, as well as before first use, when moved to different locations in respect to the original one and each time unexpected events which may affect safety occur.
Similar indications apply to wire ropes, who should always be handled, maintained and inspected by competent persons using proper procedures (see also chapters related to wire rope inspection).
When bent over stationary pins or sheaves, rope minimum breaking force is affected in respect to linear load conditions depending on D/d ratio, thus reducing its efficiency (see figure).

For moving parts, further reduction must be considered due rope internal friction and efficiency of the rotating parts.

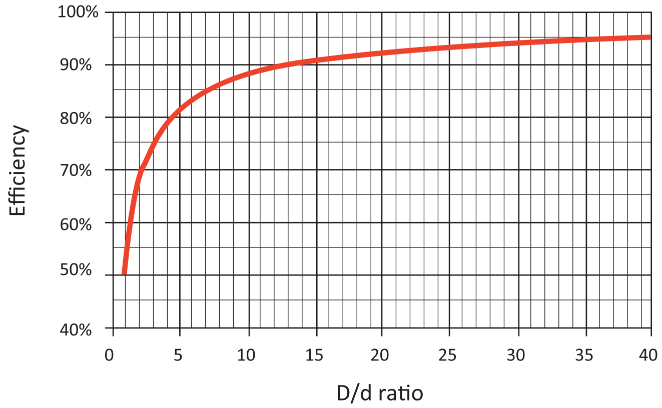


Figure 28 Reduction in rope efficiency in case of bent over stationary components

The efficiency of sheaves should also be considered when calculating the lead line load.
In case of systems having same number of rotating sheaves and parts of line (e.g. 2 falls and two rotating sheaves, like in the sketch), the lead line load can be calculated by dividing the load by the efficiency coefficient (e.g. as per Table 3: lifting 80 tons in 2 parts mode with roller bearing sheaves will give a lead line load of 80 /1.94 = 41.2 tons).
If additional rotating sheaves are used, unless otherwise specified the resulting line load should be divided by 0.96, 0.98 or 0.99 (plain, roller bearing or high efficiency sheaves) times the number of extra sheaves in respect to the rope bearing parts.

Parts of line	With plain bearing sheaves	With roller bearing sheaves	With high efficiency sheaves
1	0.96	0.98	0.99
2	1.87	1.94	1.97
3	2.75	2.88	2.94
4	3.59	3.81	3.90
5	4.39	4.71	4.85
6	5.16	5.60	5.80
8	6.60	7.32	7.65
10	7.91	8.98	9.47
12	9.11	10.6	11.3
14	10.2	12.1	13.0
16	11.2	13.6	14.7
18	12.2	15.0	16.4
20	13.0	16.4	18.1

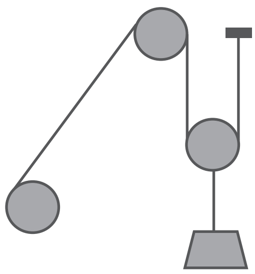


Table 3 Example of lead line factors

Rope relubrication

The main purpose of lubrication is to maintain rope performance in use and protect it against corrosion, which can determine rope discard when reaching a high severity rating.
Corrosion affects not only the residual breaking force, but also wire ductility and mechanical characteristics, therefore it should be carefully considered when inspecting a rope.

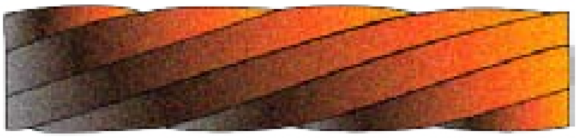


Figure 29 Heavily corroded rope

Good quality lubricants are characterized by high adherence to steel in order to resist during the passage over the reeving, light color not to obstruct possible rope damages detection and high compatibility with other products.
Drop point has to be high enough to tolerate rope storage and operating in warm environment, but with a safety borderline to denote rope overheating during use.
Since steel can suffer permanent deterioration if subjected to high temperature for extended periods, a good temperature limitation and consequent drop point is approximately 80°C.
Unless unexpected events, the protection provided by the original manufacturing lubricant is enough to prevent rope corrosion during shipment, storage and first period of use.
Lubricant conditions must be periodically checked depending on rope working type and environmental conditions.
Before relubrication, rope must be cleaned to remove scales, moisture and other contaminants.
Lubrication must be carried out on dry and clean rope using a lubricant compatible with the original one and whose amount is not excessive, as this would make difficult to inspect the rope and could lead to accumulation of debris which could generate abrasions.
Some typical lubrication modes are shown in the following figure.

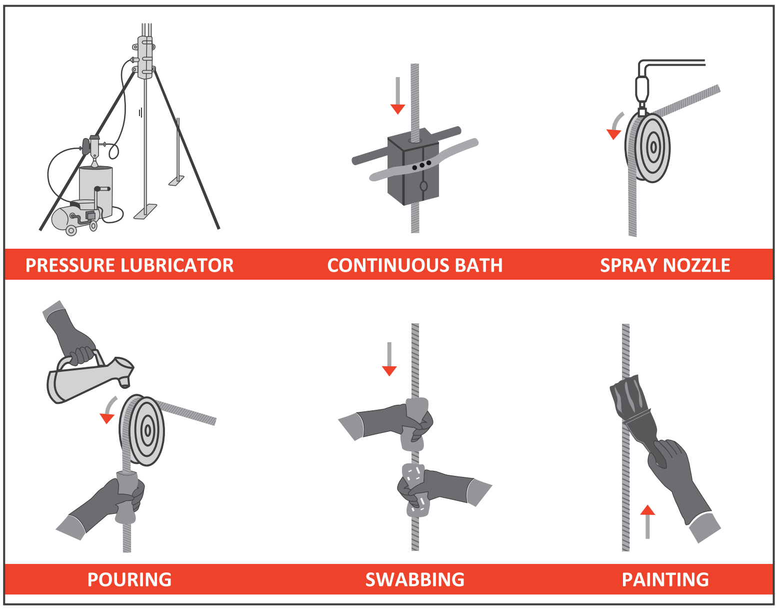


Figure 30 Typical lubrication modes

Guidelines for rope inspection

Wire ropes must be periodically inspected following regulations (e.g. ISO4309) and internal procedures to assess rope deterioration due to regular use or unexpected events and to ensure safe working conditions.
Inspections can be carried out with the aid of visual or magnetic devices: in this case, it is recommended to perform an initial inspection before rope use to have a baseline for future comparisons.
Each rope shall be inspected along its entire length or, at the discretion of the competent person, along the working length plus at least five wraps on the drum. In this case, if a greater working length is subsequently foreseen to be used, that additional portion should also be inspected.
The frequency of inspections depends on regulations, type of crane and environment, results of previous examinations, load spectrum and experience related to similar ropes and systems.
The main modes of deterioration are: broken wires or stands, decrease in rope diameter, corrosion, deformation, mechanical or heat damage and change in elastic behaviour of rope under load.
The following areas have to be inspected with particular care:

1. drum anchorage and any section close and in correspondence to rope termination
2. in case of repetitive operations, any part of the rope that lies over a sheave during crane working
3. rope portion which lies over a compensating sheave
4. cross-over zones on multilayer drums
5. rope sections subjected to revers bending over sheaves or rollers
6. section subjected to external damage, like abrasion or heat

Terminations, clamps and securing ferrules should be also inspected with special care to detect possible looseness due to vibrations, cracks, distortion, wear or corrosion.
After each periodic inspection, the competent person shall provide a rope inspection record and state a maximum time interval that shall not be exceeded before the next periodic inspection takes place.
The following sketch shows some examples of typical points which require special care during inspection.

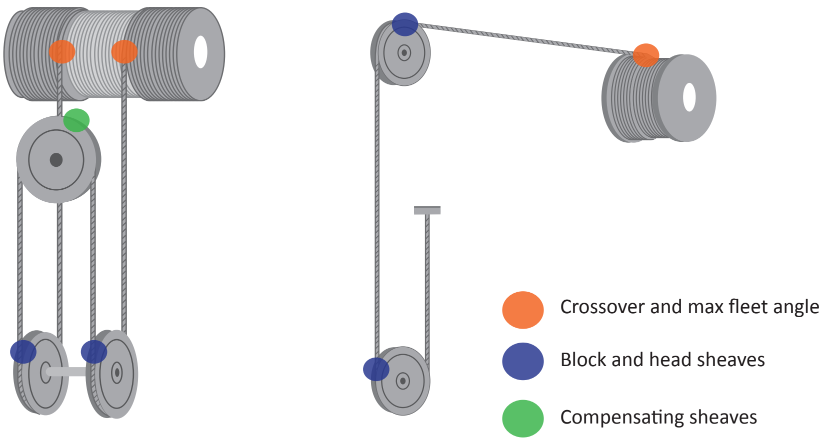


Figure 31 Areas requiring detailed inspection

Discard criteria for visible broken wires

Rope conditions have to be clearly assessed by a competent person based on discard criteria provided by regulations and internal procedures

Discard criteria depends on the nature, occurrence and location of broken wires and on the rope construction and are based on number of visible broken wires, diameter variation, corrosion and distortion or a combination of all these factors.

Number of visible broken wires takes in account only the breaks due to regular use, that indicate fatigue pile up and approaching of end of rope safe life, therefore breaks due to improper handling may not be considered in this count if not affecting safety conditions.

Breaks protruding from the rope can be removed if there is the risk that they generate further damage to the equipment or to the rope itself.

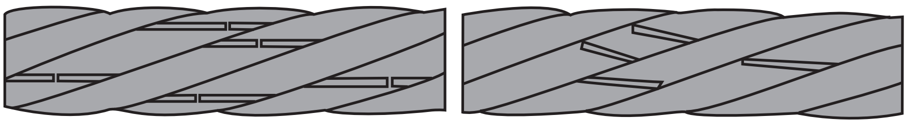


Figure 32 Crown and valley breaks due to fatigue

If groups of broken wires are found in a section of rope which do not spool on and off the drum and breaks are concentrated in adjacent strands, it might be necessary to discard the rope.

It shall be discarded as well if two or more wire breaks are found at a termination or concentrated in the valleys in a rope lay length, as this could indicate the beginning of fatigue phenomenon.

If breaks occur randomly in rope sections running through sheaves, spooled on and off a single layer drum or on crossover points of a multilayer drum, the maximum amount is determined by specific regulations (e.g. ISO 4309). Some examples of maximum allowed breaks for different rope use and constructions are shown in the following table.

Rope construction	Number of visible broken outer wires					
	On steel sheaves or single layer drum				On multi - layer drum	
	Ordinary lay		Lang lay			
	Over 6d	Over 30d	Over 6d	Over 30d	Over 6d	Over 30d
6 x 19	3	6	2	3	6	12
6 x 25, 8 x 19	5	10	2	5	10	20
6 x 26, 8 x 25	6	13	3	6	12	26
6 x 36, 8 x 26	9	18	4	9	18	36
35 x 7	3	5	3	5	5	10

Table 4 Maximum number of visible broken wires for typical rope constructions

The numbers depend on the assumption that outer wire breaks correspond to a certain number of inner wire breaks. Typically, the number of inner broken wires due to use of a Lang lay rope is higher than the number of outer broken wires, therefore damage detection is harder and the number of outer allowed breaks must be low.

On the other hand, in ordinary lay ropes more breaks occur on the outer surface, therefore they are more detectable and the allowed number is higher than the Lang lay value.

For non rotating ropes this difference is not remarkable due to their geometrical structure, therefore there is no distinction due to lay direction.

Breaks distribution along the rope can indicate fatigue beginning, therefore the number of broken wires over a significant rope length (e.g. 30d) is not proportional to the number of localized broken wire in a specific portion (e.g. 6d), which could be due to other causes to be specifically investigated.

Discard criteria for diameter decrease, deformation and corrosion

Diameter shall be periodically measured and compared to the initial reference value (i.e. recorded measurement taken immediately after receipt) to detect uniform or localized variations.
Diameter decrease has to be calculated using the following formula

$$\boxed{\text{Diameter decrease [\%]} = 100 \cdot (\text{reference diameter} - \text{measured diameter}) / \text{nominal diameter}}$$

In case of uniform decrease, the maximum allowed value is 5% in respect to nominal diameter for non rotating ropes, 7.5% for other rope constructions with steel core, 10% for fibre core ropes.
A clear localized decrease indicates a severe failure of rope core and leads to immediate rope discard.
Also in case of break of a complete strand, rope has to be immediately discarded.
Ropes showing deformations like basket, core or strand protrusion or distortion, kink or tightened loop shall be evaluated and can remain in service if the damaged portion can be removed and if the remaining part of rope is still suitable for use.
Other damages, like flattened portion or permanent bend, may not be cause of immediate discard, but they have to be inspected with higher frequency, as the affected portions are likely to deteriorate and show broken wires at faster rate than usual.
Waviness should be assessed using a straight bar and considering the gap between the rope and the cut surface (see figure): the maximum allowed gap is 1/3 the rope nominal diameter if the deformation affects a portion not running over sheaves or spooled on the drum, otherwise it has to be reduced to 1/10.

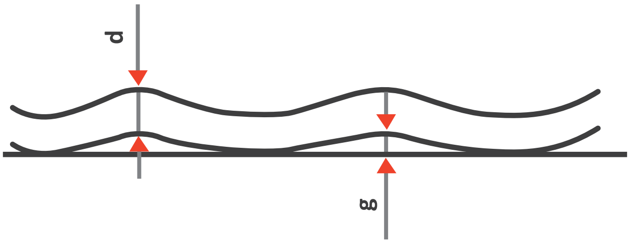


Figure 33 Waviness assessment

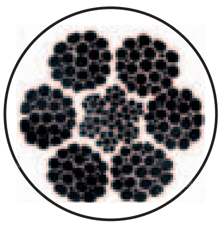


Figure 34 Internal corrosion

Corrosion should be evaluated after having wiped the rope to remove contaminating particles and should be assessed considering type and severity.
Rope should be discarded in case of heavy pitting and slack wires on the external surface, as well as in case of internal corrosion (see figure), indicated by the presence of debris extruding between the outer strands.
Rope should also be discarded in case of severe fretting corrosion, which manifests as a dry red powder and is caused by the continuous rubbing between dry wires and consequent particles oxidation.

Health and safety information

As a general indication, applicable to all types of working environment, workers must be properly trained and have all the necessary equipment and operating procedures to perform their job safely.
Steel wire rope is a composite material containing different materials, which can be identified based on the delivery note, invoice or certificate.
The main component of steel wire ropes covered by the various parts of EN 12385 is carbon steel, which may be galvanized or coated with zinc aluminium alloy.
Other components can be the fibre core, the lubricant and possible plastic filling or covering.
Ropes produced from carbon, galvanizing coated or stainless steel wires in the as-supplied condition are not considered a health hazard.
However, during any subsequent processing such as cutting, welding, grinding and cleaning, dust and fumes may be produced which contain elements that may affect the health of exposed workers.
Fibre cores are composed by synthetic or natural fibres and do not present a health hazard when handled, except in the unlikely case that the core may have decomposed into a dust which may be inhaled.
Also the concentration of toxic fumes from the cores generated during cutting will be almost negligible compared with the products generated by wire and lubricant.
Same risk of toxic fumes inhalation applies to plastic filling or covering.
The lubricants used in the manufacture of steel wire ropes normally present minimal hazard to the user, who should anyway take reasonable care to minimize skin and eye contact and also avoid breathing their vapours and mists.
Lubricants consist essentially of mixtures of oils, waxes, bitumen, resins, petroleum jelly, gelling agents and fillers with minor concentrations of corrosion inhibitors, oxidation stabilizers and tackiness additives and they are typically solid at ambient temperature.
To avoid the possibility of skin disorders, repeated or prolonged contact with mineral or synthetic hydrocarbons should be avoided and workers should always wear protective clothing and gloves.
General and local exhaust ventilation should be used to keep airborne dust or fumes below established occupational exposure standards and operators should wear approved dust and fume respirators if these values are exceeded.
Protective equipment should be worn during operations creating eye hazards, as well as gloves and other protective equipment when required.
A welding hood should be worn when welding or burning.
In the solid state, steel components of the rope present no fire or explosion hazard.
The organic elements present, like lubricants, natural and synthetic fibres and other natural or synthetic filling and covering materials are capable of supporting fire.
Ropes and components must be disposed of in accordance with local Regulations.

Appendix A Definitions

- **BREAKING FORCE**

1. **minimum breaking force (Fmin)**: specified value in kN, below which the measured breaking force (Fm) is not allowed to fall in a prescribed breaking force test and normally obtained by calculation from the product of the square of the nominal diameter (d), the rope grade (Rr) and the breaking force factor (K)
2. **minimum breaking force factor (K)**: an empirical factor used in the determination of minimum breaking force of a rope and obtained from the product of fill factor (f) for the rope class or construction, spinning loss factor (k) for the rope class or construction and the constant π/4
3. **calculated minimum breaking force (Fc.min)**: value of minimum breaking force based on the nominal wire sizes, wire tensile strength grades and spinning loss factor for the rope class or construction as given in the manufacturer's rope design
4. **minimum aggregate breaking force (Fe.min)**: specified value, in kN, below which the measured aggregate breaking force is not allowed to fall in a prescribed test and normally obtained by calculation from the product of the square of the rope diameter (d), the metallic cross sectional area factor (C) and the rope grade (Rr)
5. **measured aggregate breaking force (Fe.m)**: the sum of the measured breaking forces of all the individual wires taken from the rope
6. **spinning loss factor (k)**: the ratio between either the calculated minimum aggregate breaking force (Fe.c.min) and the calculated minimum breaking force (Fc.min) of the rope or the specified minimum aggregate breaking force (Fe.min) and the specified minimum breaking force (Fmin) of the rope, as determined from the ropemaker's design
7. **measured total spinning loss factor (km)**: the ratio between the measured breaking force (Fm) of the rope and the measured aggregate breaking force of the rope, before rope making

- **COATING**

1. **finish and quality of coating**: the condition of the surface finish of the wire e.g. uncoated (bright), zinc coated, zinc alloy coated or other protective coating and the class of coating, e.g. class B zinc coating, defined by the minimum mass of coating and the adherence of the coating to the steel below
2. **mass of coating**: the mass of coating (obtained by a prescribed method) per unit of surface area of the uncoated wire, expressed in g/m^2

- **CORE**

1. **core**: central element of a round rope around which are laid helically the strands of a stranded rope or the unit ropes of a cable laid rope
2. **fibre core (FC)**: core made from either natural fibres (NFC) or synthetic fibres (SFC) (NOTE Fibre cores are normally produced in the sequence fibres to yarns, yarns to strands and strands to rope)
3. **steel core (WC)**: core made from steel wires arranged as a wire strand (WSC) or as an independent wire rope (IWRC) (NOTE The steel core and/or its outer strands can also be covered with either fibre or solid polymer)
4. **solid polymer core (SPC)**: core consisting of a solid polymer material having a round shape or a round shape with grooves. It may also contain an internal element of wire(s) or fibre

- **CROSS SECTIONAL AREA AND MASS**

1. **fill factor (f)**: the ratio between the sum of the nominal metallic cross-sectional areas of all the wires in the rope and the circumscribed area of the rope based on its nominal diameter
2. **nominal metallic cross-sectional area factor (C)**: factor derived from fill factor and used in the calculation to determine the nominal metallic cross-sectional area of a rope (NOTE This can be expressed as C = f • π/4)
3. **nominal metallic cross-sectional area (A)**: the product of the nominal metallic cross-sectional area factor (C) and the square of the nominal rope diameter
4. **rope length mass factor (W)**: that factor which takes into account the mass of core and lubricant as well as the metallic elements
5. **nominal rope length mass (M)**: product of the length mass factor and the square of the nominal diameter

- **DIMENSIONS**

1. **dimension of round wire or strand**: the diameter of the perpendicular cross-section of the wire or strand
2. **dimension of round rope**:that diameter which circumscribes the rope cross-section
3. **outer wire factor (a)**: factor used in the calculation of the approximate diameter of the outer wires of the outer strand layer
4. **outer wire diameter (δa)**: the value derived from the product of the outer wire factor and the nominal rope diameter

- **GRADE AND TENSILE STRENGTH**

1. **rope grade (Rr)**: a level of requirement of breaking force which is designated by a number (e.g. 1770, 1960) (NOTE It does not imply that the actual tensile strength grades of the wires in the rope are necessarily of this grade)
2. **wire tensile strength grade (R)**: a level of requirement of tensile strength of a wire and its corresponding range. It is designated by the value according to the lower limit of tensile strength and is used when specifying wire and when determining the calculated minimum breaking force or calculated minimum aggregate breaking force of a rope, expressed in N/mm^2

   wire tensile strength (Rm): the ratio between the maximum force obtained in a tensile test and the nominal cross-sectional area of the test piece, expressed in N/mm^2

- **LAY**

1. **lay length (H)**: that distance (H) parallel to the longitudinal rope axis in which the outer wires of a spiral rope, the outer strands of a stranded rope or the unit ropes of a cable-laid rope make one complete turn (or helix) about the axis of the rope
2. **lay direction of rope**: the direction right (Z) or left (S) corresponding to the direction of the outer strands in a stranded rope in relation to the longitudinal axis of the rope
3. **ordinary lay (sZ or zS)**: stranded rope in which the direction of lay of the wires in the outer strands is in the opposite direction to the lay of the outer strands in the rope (NOTE The first letter denotes strand direction; the second letter denotes rope direction)
4. **lang lay (zZ or sS)**: stranded rope in which the lay direction of the wires in the outer strands is in the same lay direction as that of the outer strands in the rope (NOTE The first letter denotes strand direction; the second letter denotes rope direction)

- **ROPES**

1. **rope construction**: the detail and arrangement of the various elements of the rope
2. **rope class**: a grouping of ropes of similar mechanical properties and physical characteristics
3. **stranded rope**: an assembly of several strands laid helically in one or more layers around a core (single-layer rope) or centre (rotation-resistant or parallel-closed rope) (NOTE Stranded ropes consisting of three or four outer strands can, or cannot, have a core)
4. **single-layer rope**: stranded rope consisting of one layer of strands laid helically around a core
5. **rotation-resistant rope**: stranded rope designed to generate reduced levels of torque and rotation when loaded (NOTE Rotation-resistant ropes generally comprise an assembly of at least two layers of strands laid helically around a centre, the direction of lay of the outer strands being opposite to that of the underlying layer. Ropes having three or four strands can also be designed to exhibit rotational-resistant properties)
6. **parallel-closed rope**: stranded rope consisting of at least two layers of strands laid helically in one closing operation around a strand or fibre centre
7. **compacted strand rope**: rope in which the strands, prior to closing of the rope, are subjected to a compacting process such as drawing, rolling or swaging
8. **compacted (swaged) rope**: rope which is subjected to a compacting (usually swaging) process after closing the rope, thus reducing its diameter
9. **cable-laid rope**: an assembly of several (usually six) round stranded ropes (referred to as unit ropes) closed helically around a core(usually a seventh rope)

- **ROPE CHARACTERISTICS**

1. **torque**: torsional characteristic, the value of which is usually expressed in Nm, at a stated tensile loading and determined by test when both rope ends are prevented from rotating (NOTE Torsional characteristics can also be determined by calculation)
2. **turn**: rotational characteristic, the value of which is usually expressed in degrees or turns per unit length at a stated tensile loading and determined by test when one end of the rope is free to rotate
3. **fully preformed rope**: rope in which the wires in the strands and strands in the rope have their internal stresses reduced resulting in a rope which after removal of any serving, the wires and the strands will not spring out of the rope formation

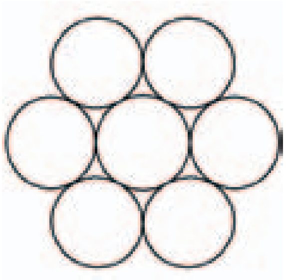
- **STRAND**

4. **strand**: an element of rope consisting of an assembly of wires of appropriate shape and dimensions laid helically in the same direction in one or more layers around a centre (NOTE Strands containing three or four wires in the first layer, or certain shaped strands (e.g. ribbon) cannot have a centre)
5. **compacted strand**: a strand which has been subjected to a compacting process such as drawing, rolling or swaging whereby the metallic cross-sectional area of the wires remains unaltered whereas the shape of the wires and the dimensions of the strand are modified
6. **Seale**: parallel lay strand construction with the same number of wires in both layers
7. **Warrington**: parallel lay strand construction having an outer layer containing alternately large and small wires and twice the number of wires as the inner layer
8. **Filler**: parallel lay strand construction having an outer layer containing twice the number of wires than the inner layer, with filler wires laid in the interstices between the layers

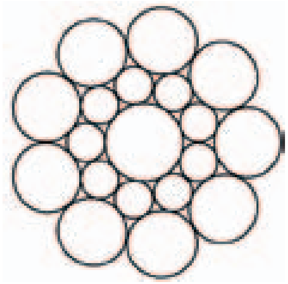
- **WIRE**

9. **outer wires**: all wires positioned in the outer layer of a spiral rope or in the outer layer of wires in the outer strands of a stranded rope
10. **inner wires**: all wires of intermediate layers positioned between the centre wire and outer layer of wires in a spiral rope or all other wires except centre, filler, core and outer wires in a stranded rope
11. **filler wires**: wires used in filler constructions to fill up the interstices between wire layers
12. **centre wires**: wires positioned either at the centre of a spiral rope or the centres of strands of a stranded rope
13. **core wires**: all wires of the core of a stranded rope
14. **load-bearing wires**: those wires in a rope which are regarded as contributing towards the breaking force of the rope
15. **serving wire or strand**: single wire or strand used for making a close-wound helical serving to retain the elements of a rope in their assembled position

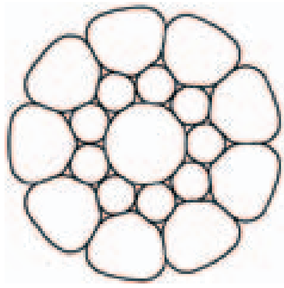
Appendix C Examples of strand constructions



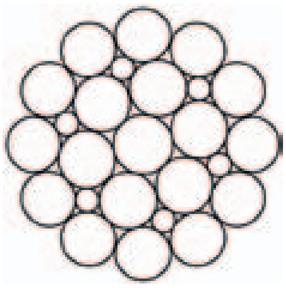
Single lay
7 (1-6)



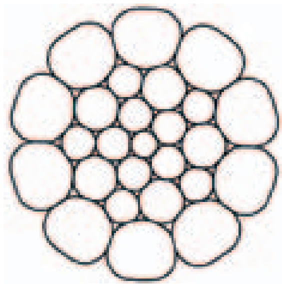
19 Seale
19S (1-9-9)



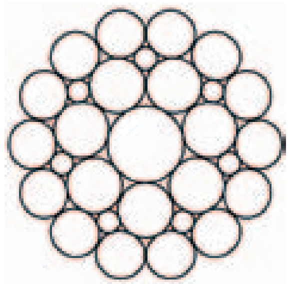
19 Seale compacted
K19S (1-9-9)



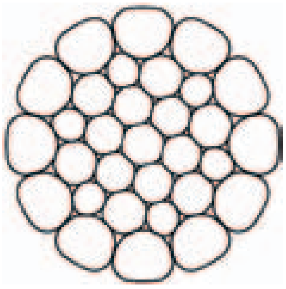
25 Filler
25F (1-6-6F-12)



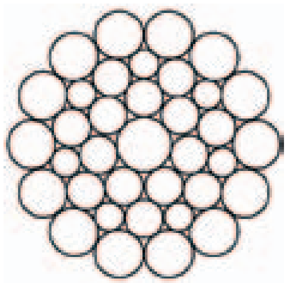
26 Warrington Seale compacted
K26WS (1-5-5+5-10)



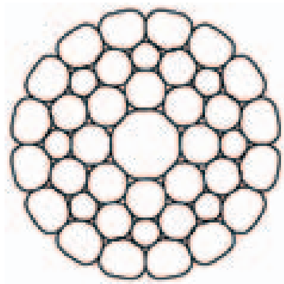
29 Filler
29F (1-7-7F-14)



31 Warrington Seale compacted
K31WS (1-6-6+6-12)



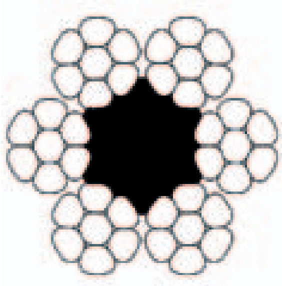
36 Warrington Seale
36WS (1-7-7+7-14)



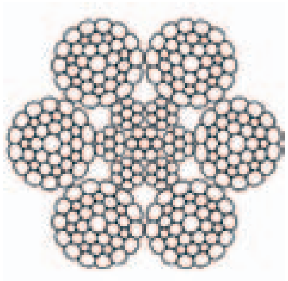
41 Warrington Seale compacted
K41WS (1-8-8+8-16)

Table 5 Examples of strand constructions

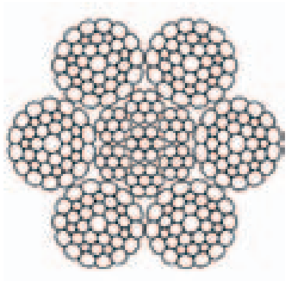
Appendix D Examples of rope constructions



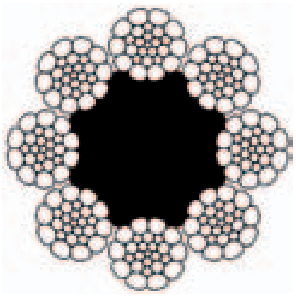
6xK7 – FC



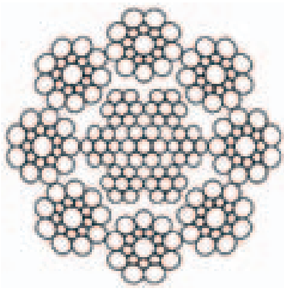
6xK36WS - IWRC



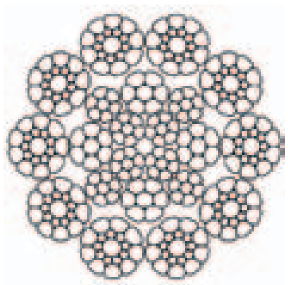
6xK36WS - PWRC



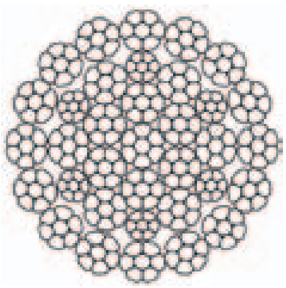
8xK26WS – FC



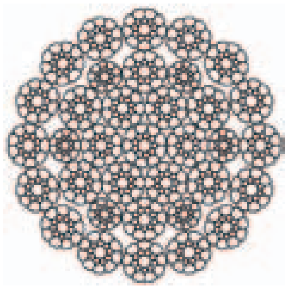
8x19S - IWRC



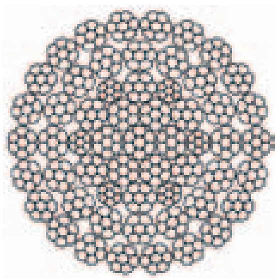
10xK19S – IWRC



35xK7



35xK19



57xK7

Table 6 Examples of rope constructions

Appendix E Fleet angle during spooling

Excessive deflection angles during rope use should be carefully considered to avoid rope permanent damage. The following tables show the recommended (green areas), borderline (yellow areas) and not recommended (red areas) fleet angles for different drum widths "W" and spooling distances "L".

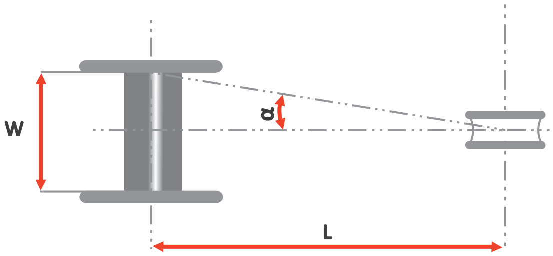


Figure 35 Spooling arrangement

Fleet angle α [deg] **Hoist ropes**

Width [m]	**Distance** [m]									
	5	10	15	20	25	30	35	40	45	50
1.0	5.7	2.9	1.9	1.4	1.1	1.0	0.8	0.7	0.6	0.6
1.1	6.3	3.1	2.1	1.6	1.3	1.1	0.9	0.8	0.7	0.6
1.2	6.8	3.4	2.3	1.7	1.4	1.1	1.0	0.9	0.8	0.7
1.3	7.4	3.7	2.5	1.9	1.5	1.2	1.1	0.9	0.8	0.7
1.4	8.0	4.0	2.7	2.0	1.6	1.3	1.1	1.0	0.9	0.8
1.5	8.5	4.3	2.9	2.1	1.7	1.4	1.2	1.1	1.0	0.9
1.6	9.1	4.6	3.1	2.3	1.8	1.5	1.3	1.1	1.0	0.9
1.7	9.6	4.9	3.2	2.4	1.9	1.6	1.4	1.2	1.1	1.0
1.8	10.2	5.1	3.4	2.6	2.1	1.7	1.5	1.3	1.1	1.0
1.9	10.8	5.4	3.6	2.7	2.2	1.8	1.6	1.4	1.2	1.1
2.0	11.3	5.7	3.8	2.9	2.3	1.9	1.6	1.4	1.3	1.1
2.1	11.9	6.0	4.0	3.0	2.4	2.0	1.7	1.5	1.3	1.2
2.2	12.4	6.3	4.2	3.1	2.5	2.1	1.8	1.6	1.4	1.3
2.3	13.0	6.6	4.4	3.3	2.6	2.2	1.9	1.6	1.5	1.3
2.4	13.5	6.8	4.6	3.4	2.7	2.3	2.0	1.7	1.5	1.4
2.5	14.0	7.1	4.8	3.6	2.9	2.4	2.0	1.8	1.6	1.4
2.6	14.6	7.4	5.0	3.7	3.0	2.5	2.1	1.9	1.7	1.5
2.7	15.1	7.7	5.1	3.9	3.1	2.6	2.2	1.9	1.7	1.5
2.8	15.6	8.0	5.3	4.0	3.2	2.7	2.3	2.0	1.8	1.6
2.9	16.2	8.3	5.5	4.1	3.3	2.8	2.4	2.1	1.8	1.7
3.0	16.7	8.5	5.7	4.3	3.4	2.9	2.5	2.1	1.9	1.7

Table 7 Recommended range of use (fleet angles) for not non rotating ropes

Fleet angle α [deg] Hoist ropes with plastic

Width [m]	Distance [m]									
	5	10	15	20	25	30	35	40	45	50
1.0	5.7	2.9	1.9	1.4	1.1	1.0	0.8	0.7	0.6	0.6
1.1	6.3	3.1	2.1	1.6	1.3	1.1	0.9	0.8	0.7	0.6
1.2	6.8	3.4	2.3	1.7	1.4	1.1	1.0	0.9	0.8	0.7
1.3	7.4	3.7	2.5	1.9	1.5	1.2	1.1	0.9	0.8	0.7
1.4	8.0	4.0	2.7	2.0	1.6	1.3	1.1	1.0	0.9	0.8
1.5	8.5	4.3	2.9	2.1	1.7	1.4	1.2	1.1	1.0	0.9
1.6	9.1	4.6	3.1	2.3	1.8	1.5	1.3	1.1	1.0	0.9
1.7	9.6	4.9	3.2	2.4	1.9	1.6	1.4	1.2	1.1	1.0
1.8	10.2	5.1	3.4	2.6	2.1	1.7	1.5	1.3	1.1	1.0
1.9	10.8	5.4	3.6	2.7	2.2	1.8	1.6	1.4	1.2	1.1
2.0	11.3	5.7	3.8	2.9	2.3	1.9	1.6	1.4	1.3	1.1
2.1	11.9	6.0	4.0	3.0	2.4	2.0	1.7	1.5	1.3	1.2
2.2	12.4	6.3	4.2	3.1	2.5	2.1	1.8	1.6	1.4	1.3
2.3	13.0	6.6	4.4	3.3	2.6	2.2	1.9	1.6	1.5	1.3
2.4	13.5	6.8	4.6	3.4	2.7	2.3	2.0	1.7	1.5	1.4
2.5	14.0	7.1	4.8	3.6	2.9	2.4	2.0	1.8	1.6	1.4
2.6	14.6	7.4	5.0	3.7	3.0	2.5	2.1	1.9	1.7	1.5
2.7	15.1	7.7	5.1	3.9	3.1	2.6	2.2	1.9	1.7	1.5
2.8	15.6	8.0	5.3	4.0	3.2	2.7	2.3	2.0	1.8	1.6
2.9	16.2	8.3	5.5	4.1	3.3	2.8	2.4	2.1	1.8	1.7
3.0	16.7	8.5	5.7	4.3	3.4	2.9	2.5	2.1	1.9	1.7

Table 8 Recommended range of use (fleet angles)
for not non rotating ropes with plastic impregnated core

Fleet angle α [deg] Rotation resistant ropes

Width [m]	Distance [m]									
	5	10	15	20	25	30	35	40	45	50
1.0	5.7	2.9	1.9	1.4	1.1	1.0	0.8	0.7	0.6	0.6
1.1	6.3	3.1	2.1	1.6	1.3	1.1	0.9	0.8	0.7	0.6
1.2	6.8	3.4	2.3	1.7	1.4	1.1	1.0	0.9	0.8	0.7
1.3	7.4	3.7	2.5	1.9	1.5	1.2	1.1	0.9	0.8	0.7
1.4	8.0	4.0	2.7	2.0	1.6	1.3	1.1	1.0	0.9	0.8
1.5	8.5	4.3	2.9	2.1	1.7	1.4	1.2	1.1	1.0	0.9
1.6	9.1	4.6	3.1	2.3	1.8	1.5	1.3	1.1	1.0	0.9
1.7	9.6	4.9	3.2	2.4	1.9	1.6	1.4	1.2	1.1	1.0
1.8	10.2	5.1	3.4	2.6	2.1	1.7	1.5	1.3	1.1	1.0
1.9	10.8	5.4	3.6	2.7	2.2	1.8	1.6	1.4	1.2	1.1
2.0	11.3	5.7	3.8	2.9	2.3	1.9	1.6	1.4	1.3	1.1
2.1	11.9	6.0	4.0	3.0	2.4	2.0	1.7	1.5	1.3	1.2
2.2	12.4	6.3	4.2	3.1	2.5	2.1	1.8	1.6	1.4	1.3
2.3	13.0	6.6	4.4	3.3	2.6	2.2	1.9	1.6	1.5	1.3
2.4	13.5	6.8	4.6	3.4	2.7	2.3	2.0	1.7	1.5	1.4
2.5	14.0	7.1	4.8	3.6	2.9	2.4	2.0	1.8	1.6	1.4
2.6	14.6	7.4	5.0	3.7	3.0	2.5	2.1	1.9	1.7	1.5
2.7	15.1	7.7	5.1	3.9	3.1	2.6	2.2	1.9	1.7	1.5
2.8	15.6	8.0	5.3	4.0	3.2	2.7	2.3	2.0	1.8	1.6
2.9	16.2	8.3	5.5	4.1	3.3	2.8	2.4	2.1	1.8	1.7
3.0	16.7	8.5	5.7	4.3	3.4	2.9	2.5	2.1	1.9	1.7

Table 9 Recommended range of use (fleet angles)
for non rotating ropes

APPENDIX F QUICK CALCULATOR

Quick calculation for general purpose evaluations or for preliminary design feasibility can be made using the following formulas and tables, which provide a set of relevant nominal values.

MBF [kN] = $K \cdot d^2$ (d = nominal diameter [mm])
Mass [kg/m] = $k_m \cdot d^2$
Metallic area (A) [mm²] = $0.785 \cdot f \cdot d^2$
Axial stiffness (EA) [MN] = $E \cdot 0.785 \cdot f \cdot d^2/1000$
Elastic elongation [$\frac{\Delta l}{l}$] = Load [kN] / (EA•1000)
Rope torque [Nm] = $t \cdot d \cdot$ load [kN]

Rope type	Fill factor (f)	MBF factor (K)	Mass factor (k_m)	Emodulus [kN/mm²]	Torque factor (t)* Lang	Torque factor (t)* Reg	Ref. lay factor (k_L)	Turn [degrees/lay]* Lang	Turn [degrees/lay]* Reg
Non rotating (d up to 40 mm)	0.725	0.86 - 1.00	0.0049	127	0.02	0.009	7	2.5	2
Non rotating (d up to 100 mm)	0.740	0.86 - 0.98	0.0049	130	0.012	0.007	7	1.5	1
Non rotating (d over 100 mm)	0.725	0.83 - 0.86	0.0049	128	0.008	0.001	7	0.75	0.5
10 strands compacted spin	0.695	0.81 - 0.95	0.0047	125	0.05	0.045	6.5	12	8
10 strands compacted	0.695	0.82 - 0.96	0.0047	127	0.12	0.090	6.5	140	100
8 strands compacted	0.680	0.80 - 0.95	0.0046	125	0.11	0.085	6.5	120	90
6 strands compacted	0.670	0.79 - 0.92	0.0045	122	0.1	0.078	6.5	100	80
6 strands not compacted IWRC	0.590	0.71 - 0.85	0.0042	122	0.1	0.078	6.5	100	80

*Nominal values at 20% MBF for trained rope

TABLE 10 TYPICAL ROPE PROPERTIES

1	kg/m	=	0.672	lbs/ft
1	m	=	3.28	ft
1	mm	=	0.039	inch
1	kg	=	2.205	lbs
1	lb	=	0.0005	short t (ton)
1	metric t (tonne)	=	1.10	short t (ton)
1	metric t (tonne)	=	0.984	long t
1	kN	=	0.102	metric tf
1	N/mm² (MPa)	=	145	psi

1	lbs/ft	=	1.49	kg/m
1	ft	=	0.305	m
1	inch	=	25.4	mm
1	lbs	=	0.454	kg
1	short t (ton)	=	2000	lb
1	short t (ton)	=	0.907	metric t (tonne)
1	long t	=	1.016	metric t (tonne)
1	metric tf	=	9.81	kN
1	psi	=	0.0069	N/mm² (MPa)

TABLE 11 CONVERSION FACTORS

Appendix G Minimum rope information

When providing an enquiry or a purchase order, at least the following information should be supplied:

1. reference standard, i.e. EN 12385-4
2. quantity and length
3. nominal diameter
4. rope class or construction
5. core type
6. rope grade
7. wire finish
8. lay direction and type (single layer ropes are normally manufactured right hand ordinary lay unless otherwise stated by the purchaser)
9. preformation (outer strands of single layer and parallel-closed ropes are normally preformed during manufacture. The purchaser should specify any particular preformation requirements)
10. lubrication (at least the strands are lubricated during manufacture. The purchaser should specify any particular lubrication requirements)
11. type of inspection document - refer EN 12385-1
12. any particular marking requirements
13. any particular packaging requirements
14. required minimum breaking force

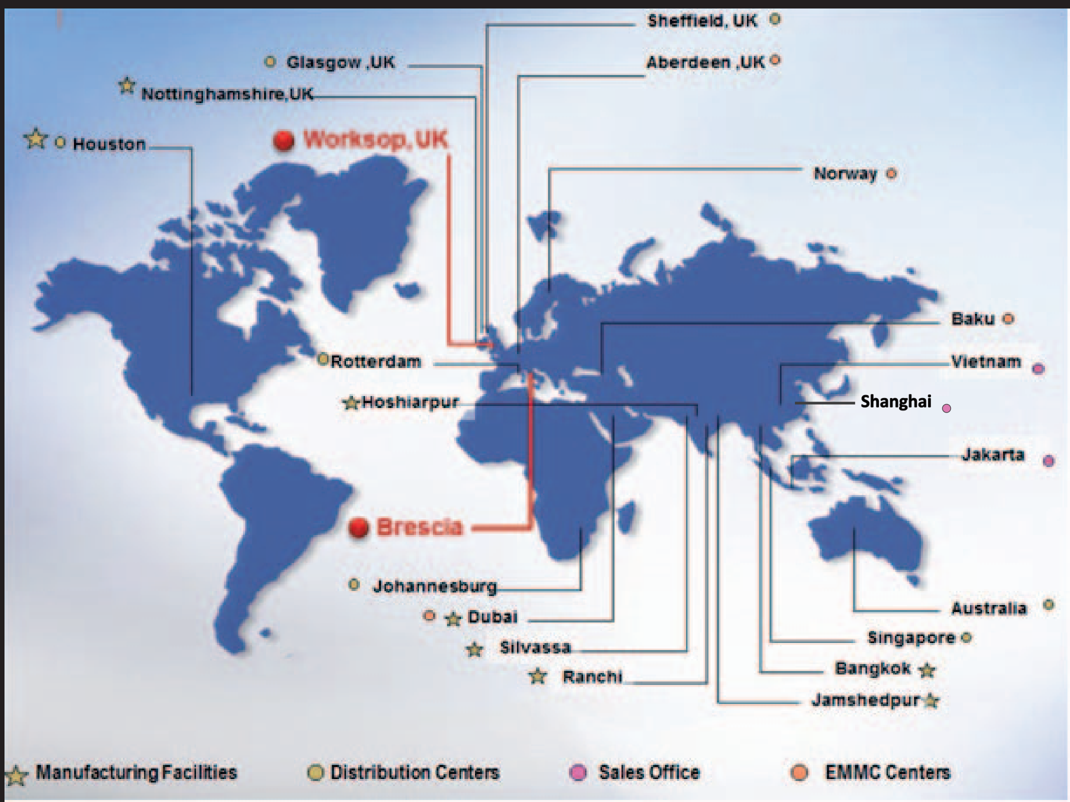
Appendix H Reference documents

The following list indicates some of the most relevant documents about wire ropes definitions, use, maintenance and inspection.

- EN 12385-1:2009 – Steel wire ropes – Safety Part 1: General requirements
- EN 12385-2:2008 – Steel wire ropes – Safety Part 2: Definitions, designation and classification
- EN 12385-3:2008 – Steel wire ropes – Safety Part 3: Information for use and maintenance
- EN 12385-4:2008 – Steel wire ropes – Safety Part 4: Stranded ropes for general lifting applications
- EN 13411-3:2011 – Terminations for steel wire ropes – Safety Part 3: ferrules and ferrule-securing
- EN 13411-4:2011 – Terminations for steel wire ropes – Safety Part 4: metal and resin socketing
- EN 13411-5:2011 – Terminations for steel wire ropes – Safety Part 5: U-bolt wire rope grips
- EN 13411-6:2011 – Terminations for steel wire ropes – Safety Part 6: Asymmetric wedge socket
- EN 13411-7:2011 – Terminations for steel wire ropes – Safety Part 7: Symmetric wedge socket
- EN12927– Part 8 – Magnetic rope testing
- ISO 17558:2006 – Steel wire ropes – Socketing procedures – Molten metal and resin socketing
- ISO 4309:2010 – Cranes – Wire ropes – Care and maintenance, inspection and discard
- IMCA M171 – Crane specification document
- IMCA M179 – Guidance on the use of cable laid slings and grommets
- IMCA M187 – Guidelines for lifting operations
- IMCA M194 – Wire rope integrity management for vessels in the offshore industry
- IMCA M197 – Guidance on non-destructive examination (NDE) by means of magnetic rope testing
- API 9A/ISO 10425:2003 – Steel wire ropes for the petroleum and natural gas industries – Minimum requirements and terms of acceptance
- API RP 9B:2005 – American Petroleum Institute recommended practice for application, care and use of wire rope for oilfield services
- Wire rope technical board – Wire rope user's manual 4th edition

VARUNA PROJECT

In order to deal with the new challenges given by industrial and offshore heavy lifting applications, Usha Martin group has opened Varuna project, which is leading to the built up of a brand new manufacturing facility.
The new facility is currently under construction in Worksop (UK) and will accommodate an efficient production line, including two dedicated stranders and a state of the art closer.
The new machines will be capable to produce large size ropes with six strands, multistrand and non rotating construction up to 300ton weight.
The location of the plant achieves the best compromise between logistic and expertise: only 60 miles to the sea without resigning the skills of Brunton Shaw people.
All rope design will be analysed and fine-tuned by Usha Martin Italia in order to meet the required product specifications, reliability and production efficiency.
Varuna products will be focused on the most typical rope constructions and size, to supply customers the right product in swift delivery.



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