Ropes

Rope has been used on board vessels since man first went to sea. It can be made from many different materials, such as natural fibre, synthetic fibre, metal wire, or any combination. It can be classified as fibre rope and wire rope. Fibre rope is further divided into natural and synthetic.

Natural Fibre Ropes Natural fibre rope is made from fibres such as abaca, hemp, sisal, coconut and cotton, hemp being the most common.

Manila Manila is made from the fibre of abaca, a wild banana plant grown largely in the Philippines. It took its name from the Port of Manila, from which it is exported. Manila rope is soft, glossy, smooth, pliable and has good stretch. It has the greatest tensile strength of all natural fibre rope, but when wet loses half its tensile strength and has only about half the strength of a similar sized synthetic line.

Hemp Hemp is made from the stem of the plant cannabis sativa. It has the same tensile strength as manila, and is primarily used for making small cordage. Its main advantage is that it doesn’t shrink or swell when wet.

Sisal Sisal is a hard, hairy fibre with three quarters the tensile strength of manila; it is made from the leaves of the tropical plant Agave Sisalana, of the cactus family. It is a cheaper grade of rope, often used when other types are not available and mostly for mooring lines.

Cotton Cotton is soft and pliable. Its tensile strength is slightly less that sisal’s and a lot less than manila’s; many cotton ropes have a synthetic core to increase their strength. Cotton has low resistance to rot, oils, gasoline, grease, and most chemicals.

Use and care of natural rope Natural fibre rope is severely affected by chemicals, charring and abrasion. When stored in a humid environment, it will rot and decay rapidly and will lose its tensile strength.

- Natural fibre rope should be uncoiled by pulling the rope up from the eye. To prevent kinking, right-laid rope should be uncoiled in a counterclockwise direction; conversely, left-laid rope should be uncoiled in a clockwise direction.

- Coil right-laid rope right-handed or clockwise; conversely, left-laid rope should be coiled left-handed or counter clockwise.

- Rope should be stored in a dry, well-ventilated place to prevent the mildew and dry rot that greatly decrease its life.
- Avoid any contact with acid or any chemicals, so do not store rope in the same compartment as these materials.

- Inspect natural fibre rope frequently for deterioration. Open the lay and inspect the fibres. Powdery residue and broken fibres indicate internal wear, so use with care until replacement.

- Do not lubricate ropes, but the standing rigging should be treated regularly with tar oil and coal tar for protection and to prevent deterioration.

- Whip all rope ends.

- Flake down braided and plaited rope.

- Keep rope from touching stays, guys, or other standing rigging.

- When surging rope around bitts, take off enough turns for the rope to surge smoothly and not jerk.

- If rope becomes chafed or damaged, cut and splice; a good splice is safer than a damaged section.

- Dragging a rope over sharp or rough objects will cut or break the outer fibres. When line is dragged on the ground, particles are picked up that eventually work their way in, cutting the inner strands.

- Natural fibre rope exposed to the atmosphere deteriorates about 30 percent in 2 years from weathering alone.

**Synthetic Fibre Ropes**

Synthetic fibre ropes are made from nylon, polyester, polypropylene, polyethylene and aramid. Synthetic fibre rope is stronger and lasts longer than natural rope. It is also more flexible and easier to handle, and take less space for storage. It is therefore more popular than natural rope.

**Nylon**

Nylon is a man-made fibre with a complex form structure of carbon, nitrogen, oxygen and hydrogen. It has higher resistance to abrasion, higher tensile strength (3 or 4 times that of manila), more elasticity (up to 40%) and more durability than natural rope, and will not rot or mildew. It resists moisture and most chemicals such as mineral oils and greases, but is affected by paint, linseed oil or acids. When wet, nylon becomes slippery and loses about 10% to 20% of its strength. When under excessive load, nylon will break without warning. Hence it is good for mooring line, but should not be used as tow line.
**Polypropylene**

Polypropylene is lightweight, water resistant and floats. It has good resistance to rotting, mildew, and abrasion and moderate elasticity; is easily affected by heat; is difficult for forming knots or hitches; and is excellent for use as tow line.

**Polyethylene**

Polyethylene has similar characteristics to polypropylene. It is lightweight, water resistant and floats; resists chemicals and abrasion; has moderate elasticity; is difficult for forming knots or hitches; and is excellent for tow line.

**Polyester**

Polyester was formerly known as Dacron and Terylene. It has high strength (but less than nylon), but low elasticity. It has high resistance to abrasion and temperature; similarly to nylon, and is not easily damaged by water, sunlight, or most chemicals such as acids, oils and organic solvents, etc. Also similarly to nylon, polyester will not float and should not be used for tow line.

**Aramid**

Aramid fibre has high tensile strength and heat resistance; low shock absorbing ability; is easily damaged by abrasion; and is difficult for forming knots or hitches.

**Safety precautions for handling of synthetic fibre rope**

Synthetic fibre rope should not be uncoiled in the same way as natural rope, which is by pulling the end from the eye, but should be uncoiled similarly to wire rope. Right-handed synthetic fibre rope should be coiled clockwise on the reel, and left-handed should be coiled counter-clockwise.

- Synthetic fibre rope has a lower coefficient of friction, so great care must be taken when paying or easing out the line through the bitts. Power should never be used by surging.
- When parting under tension, synthetic fibre rope will snap back, so the rope handler should never stand in the direct line of pull when a rope is under tension.
- Synthetic rope has poor knot-holding characteristics.

**Construction of Fibre Ropes**

There are various types of construction of rope, such as three-strand plain laid, plaited, and double-braided, the most popular of which is three-strand laid. Other types found on board include eight-strand plaited, twelve-strand braided, etc.

**Construction of Fibre Three-Strand Laid Rope**

Fibres are twisted into yarns or threads; the yarns are twisted in the opposite direction into strands, and the strands are twisted in the first direction, making rope. Rope can have various numbers of strands, and the direction in which the strands are twisted determines the lay of the rope. If the strands are twisted to the right, the rope is said to be right-laid; if to the left, left-laid.
**Construction of Fibre Plaited Rope**

Plaited rope is made of 8-strands, grouped in 4 pairs. It is constructed by laying two pairs of strands left-handed, and two pairs right-handed. This type of lay does not kink, and has more flexibility. Many mooring lines used on board nowadays are the eight-strand plaited type. Splicing this type of lay, such as eyes for mooring line, is more complicated than for standard three-laid, and will be discussed later in this section.

**Fibre Plaited Rope**

**Construction of Fibre Braided Rope**

Nowadays, braided synthetic rope is the most popular. Some are stronger than many laid ropes. This rope has low elasticity, does not stretch as much as other types of laid rope, will not kink or harden under strain, and, like plaited rope, it does not kink and has more flexibility. There are various types of braided rope, but mainly classified into two types as single and double braid:

**Fibre Braided Rope**

- **Single Braid**
  
  Single braid is usually made from three strands, sometimes four, braided together; it is used for small line, such as flag halyards.

- **Double Braid**
  
  Double braid consists of two hollow-braided ropes, one inside the other. One is the core, which is made of large single yarns in a slack braid. The cover, known as the Braid Jacket, is made of large single yarns, but in a tight braid that compresses and holds the core.
Wire Ropes  Wire rope is made of steel or other metal, except for its core, which is likely to be fibre or metal wire. Wire rope consists of three components: core, wire and strand.

The core acts as the foundation to keep the wire rope round, as a shock absorber when the wire rope is under strain, and as a reservoir for lubricant. Cores can be natural fibre, synthetic fibre, strand wire or independent wire rope core (IWRC). The wire core is stronger than fibre core, and is used where conditions such as high temperatures would damage the fibre.

The wires are laid around an axis consisting of a wire or fibre at the centre to form strands. Strands are laid around a core to form the wire rope. The number of wires in a strand varies according to the intended purpose of the rope.

Wire rope is classified by:

- Number of wires making up the strand
- Number of strands making up the wire rope
- Type of core
- Strand construction
- Type of lay
- Addition type of lubrication in the core and the strands; type and grade of wire, etc.

Strands and wires  Standard wire rope has six strands. Wire rope classified as 6x36 has 6 strands of 36 wires per strand. Similarly, 7x19 rope has 7 strands of 19 wires per strand. Rope that has more small wires in the strand is more flexible, but less resistant to external abrasion; rope with fewer large wires in the strand is less flexible, but more resistant to abrasion.

Types of lay  Lay refers to the direction of winding of the wires in the strands and the strands in the rope. Both may be wound in the same direction, or each in opposite directions.
Regular Lay
Most rope used in marine operations has the strands and wires wound in opposite directions. The most common is the Right-Hand Regular Lay, in which the strands in the rope are twisted to the right and the wires in the strands are twisted to the left. In the Left-Hand Regular Lay, strands in the rope are twisted to the left and the wires in the strands are twisted to the right.

.lang lay
In lang lay, the strands and wires are twisted in the same direction. In Right-Hand Lang Lay, both strands in the rope and wires in the strands are twisted to the right, while in Left-Hand Lang Lay, both strands in the rope and wires in the strands are twisted to the left.

Alternate Lay
In Right-Hand Alternate Lay, strands are twisted to the right, and in Left-Hand Alternate Lay, the strands are twisted to the left. The wire in the strands for both Right-Hand and Left-Hand Alternate Lay are twisted in a right and left direction in alternating strands.

Wire ropes
measurement
Whatever its grade, wire rope is usually measured by its diameter. To measure wire rope correctly, the calliper should be placed so that the outermost points of the strands will be touching the jaws of the calliper, as shown.
Wire ropes should be inspected frequently for broken wires (fishhooks), kinks, and worn or corroded spots. Frequency of inspection depends on how often the rope is used. The inspection parts should be chosen where the failure would be most likely to occur, such as the end of the wire, the section where the wire usually contacts the sheaves, etc. The inspection includes:

1. **Measuring Diameter**
   If the diameter is reduced by one-half, the wire is unsafe.

2. **Measuring the Length of Rope Lay**
   If the length of strand increases with the loss of the rope diameter, then there might be internal break-up or core destruction. If the length of strand increases without the loss of the rope diameter, then the rope is probably unlaying and further inspection should be made to determine the cause.

3. **Search for Broken Wire**
   Carefully search for broken wires, particularly in critical areas such as at pick-up points where stresses are concentrated. If the number of broken wires reaches the maximum allowable permitted per stand or per rope lay, extend the search to other sections and, if internal wire breaks or core damage are suspected, then make an internal inspection. A rule of thumb is that if six or more broken wires are seen in one length of lay, then the wire rope is unsafe, and should be replaced immediately.

**Method of measuring rope lay**
One rope lay is the length along the rope which a single strand makes through one complete spiral or turn around the core. Place the rope on a flat surface; from the rope, draw a straight line perpendicular to it marking one particular strand, count off the number of strands in the rope, then draw another line where the same strand appears again; measure the distance between two lines, which should be the length of the rope lay.

**Alternative method of measuring rope lay**
Another method of measuring the length of rope lay is using ordinary carbon paper, with the carbon side faced to blank white paper. Firmly hold the paper and the carbon on the rope where the carbon is between the rope and the paper. The image of the strands will be printed on the paper; pick one image of strand; from its end, draw a line, then count the number of the strands, then draw another
line at opposite end; measure the distance between two lines, which should be the length of the rope lay. The measured distance is then compared with the previous records.

**Handling of wire rope**

Wire rope should be taken care of to keep it good condition. There are various methods of handling wire rope, as follows:

**Kinking**

When handling loose wire rope, small loops frequently form in the slack portion of the rope. If any tension is applied on either part of the rope, a kink will develop, resulting in unlaying of the rope; this decreases the strength of the rope. As soon as a kink is noticed, uncross the ends by pushing them apart and straighten out the rope.

**Seizing**

Any loose end of wire rope should be seized. Before cutting the wire rope, both sides of the cut should be seized to prevent the strands from jumping when coming loose, which can cause injury. Annealed wire should be used for seizing, with every turn tight and close together; the two ends will be twisted together and tucked into the groove between two strands.

**Unreeling, spooling and coiling**

When removing wire rope from a reel, make sure the reel is rotated by mounting the reel on a pipe or rod supported by two uprights. When spooling wire rope onto the reel, the wire rope tends to roll in the opposite direction from the lay; therefore, start a right-laid wire rope at the left and work toward the right when spooling over the top of the reel. When spooling under the reel, start at the right and work toward the left. Left-laid wire rope is handled the opposite way, of course.

When coiling wire rope, small loops or twists can form; to prevent this, right-lay wire rope should be coiled clockwise and left-lay wire rope coiled counter-clockwise.

**Cleaning and lubricating**

Dirt, grit, rust, foreign materials or old lubricant should be removed carefully before applying new lubricant, especially in spaces between strands. Lubricating wire rope is necessary after use to get longer service. Lubrication helps to prevent oxidation. If possible, a brush should be used to apply lubricant.

**Reversing Ends**

The wear and fatigue on a rope is more severe at some points than at others. Reversing rope is therefore necessary, so the stronger parts of the rope will be at the points of greater wear and fatigue. Reversing wire rope will produce longer service. During the reversing process, if possible, the part showing wear and fatigue, usually near the end, should be cut off before reattachment to the drum.

**Storing**

Wire rope should be coiled on a spool and stored in a dry place to reduce corrosion. It should be lubricated before storing, and should not be stored in the same compartment as chemicals.
Size of sheaves and drums

The size of the sheaves and drums used for wire rope should be chosen carefully, because when a wire is bent over a sheave or drum, each wire is bent to conform to the curvature, and the wires slide against each other lengthwise. The smaller the diameter of the sheave or drum, the greater the bending and sliding. The minimum recommended sheave and drum diameter is 20 times the diameter of the rope. For example, for 5/8-inch rope: $20 \times \frac{5}{8} = 12 \ 1/2$-inch sheave. If a 12 1/2-inch sheave is not on hand, the next larger size can be used; never use a smaller size.

Drum winding

When winding the wire rope to the drum, the rope must be wound evenly, and tightly especially the first layer. As the rope always has the tendency to roll due to the lay direction and the tension, there are methods for winding the rope onto the drum due to its lay and winding direction. The hand rules are a convenient method to determine the way to wind the rope onto the drum correctly. As in the following figures, the forefinger is extended in direction of the rope leaving the drum, while the thumb is pointing toward the flange, indicate the side of flange that the rope should be started with. For the right-hand lay rope, the right hand is used. If the rope is overwinding, the palm should be facing down and if underwinding, the palm should face up. Similarly, the left hand is used for the left-hand lay rope. If overwinding then the palm faces down, and if underwinding the palm faces up.

For right-hand lay rope

- **Overwinding**
  - Use right hand
  - Palm down

- **Underwinding**
  - Use right hand
  - Palm up

For left-hand lay rope

- **Overwinding**
  - Use left hand
  - Palm down

- **Underwinding**
  - Use left hand
  - Palm up
Calculation of Capacity of Stowage Reel

Volume available = Volume occupied

\[
\left[ \pi \left( h + \frac{c}{2} \right)^2 - \pi \left( \frac{c}{2} \right)^2 \right]w = l \times d^2
\]

\[
\left[ \left( h^2 + hc + \frac{c^2}{4} \right) - \frac{c^2}{4} \right] \times (w \times \pi) = l \times d^2
\]

\[
(h^2 + hc)(w \times \pi) = l \times d^2
\]

\[
(h + c)(h \times w \times \pi) = l \times d^2
\]

Capacity (I) = \[
\frac{(h + c)(h \times w \times \pi)}{d^2}
\]

where
- \(d\) is the diameter of wire
- \(l\) is the length of wire

\[\text{Overwind}\]

\[\text{Underwind}\]
Example 1  Let \( h = 1 \text{ m} \quad w = 2 \text{ m} \quad c = 0.5 \text{ m} \quad d = 50 \text{ mm} \)

\[
\text{Capacity (l)} = \frac{(h+c)(h\times w \times \pi)}{d^2} = \frac{(1+0.5)(1\times 2 \times \pi)}{0.05^2} = 3770 \text{ m}
\]

Strength of Ropes  The strength of rope depends upon the construction, the size (diameter) and the type of materials from which it is made. With new rope, the manufacturer should provide the specifications, such as Breaking Strength (BS). The Safe Working Load (SWL) can be found by dividing the breaking strength by Safety Factor (SF). The safety factor is the factor to provide a margin of safety between the applied tensile forces and the breaking strength of the rope. As the rope gets older, wear and corrosion occur; its safety factor increases thus reducing the SWL. If the information on breaking strength is not available, then the following computations can be used to find the approximate BS and SWL in tonnes with the safety factor equalling 6, and D will be in millimetres.

<table>
<thead>
<tr>
<th>Material</th>
<th>Breaking Strength (tonne)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manila</td>
<td>( 2D^2 / 300 )</td>
</tr>
<tr>
<td>Polypropylene / Polythene</td>
<td>( 3D^2 / 300 )</td>
</tr>
<tr>
<td>Terylene</td>
<td>( 4D^2 / 300 )</td>
</tr>
<tr>
<td>Nylon</td>
<td>( 5D^2 / 300 )</td>
</tr>
</tbody>
</table>

Example 2  Calculate breaking strength and SWL of 12 mm in diameter of manila rope with safety factor equals 6:

\[
\text{Breaking Strength} = \frac{2D^2}{300} = \frac{2(12)^2}{300} = 0.96 \text{ tonnes} = 960 \text{ kg}
\]

\[
\text{Safe Working Load} = \frac{\text{Breaking Strength}}{\text{Safety Factor}} = \frac{960}{6} = 160 \text{ kg}
\]
Example 3 Calculate the size of nylon rope that is used for the stress on hauling part is about 1.5 tonnes:

\[
\text{Breaking Strength} = \frac{5D^2}{300} \quad \text{Safety Factor} = 6
\]

\[
\text{Safe Working Load} = \frac{\text{Breaking Strength}}{\text{Safety Factor}} = \frac{5D^2}{6 \times 300} = \frac{5D^2}{1800}
\]

\[
\text{Safe Working Load} = 1.5 = \frac{5D^2}{1800}
\]

\[
D = \sqrt{\frac{1.5 \times 1800}{5}} = 23.2\text{mm} \quad \therefore \quad \text{Diameter} = 24\text{mm}
\]

Since there are many different types and constructions of wire rope, it is not possible to give a simple formula for calculating the SWL, so always refer to the manufacturer's specifications. The following are formulas to calculate some standard popular types of wire rope if the manufacturers' specifications are unavailable.

<table>
<thead>
<tr>
<th>Wire Rope (6×12)</th>
<th>15D²/500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire Rope (6×24)</td>
<td>20D²/500</td>
</tr>
<tr>
<td>Wire Rope (6×37)</td>
<td>21D²/500</td>
</tr>
</tbody>
</table>

Calculate the size of steel wire rope, constructed as 6 x 12, that can be used if the stress on the hauling part of the wire rope is 3 tonnes, given safety factor equals 5.

\[
\text{Breaking Strength} = \frac{15D^2}{500} \quad \text{Safety Factor} = 5
\]

\[
\text{Safe Working Load} = \frac{\text{Breaking Strength}}{\text{Safety Factor}} = \frac{15D^2}{5 \times 500} = \frac{15D^2}{2500}
\]

\[
\text{Safe Working Load} = 3 = \frac{15D^2}{2500}
\]

\[
D = \sqrt{\frac{3 \times 2500}{15}} = 22.4\text{mm} \quad \therefore \quad \text{Diameter} = 23\text{mm}
\]