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Maintenance of Wire Rope Systems for Movable Structures

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Introduction

Lubricant is considered the life blood of the wire rope machine. In order to maximize service life and wear protection a good lubricant is required to be applied during manufacturing and at regular intervals. These actions can reduce unnecessary maintenance costs and downtime extending the operational life of wire rope regardless of the application. Experience shows us the majority of steel wire ropes in use today are removed from service due to the effects of corrosion. The most effective method to deter corrosion is to galvanize the individual wires in the cable forming a zinc layer between the environment and the steel strength member. The use of zinc coated high carbon steel wire in the fabrication of cables for the movable bridge industry has been practiced for many years. New methods and materials for the galvanization of wires have become prominent in the industry in the past few years providing significant life cycle increases. With this increase in life comes the important requirement to inspect and maintain the products to ensure safe and effective use of the structure.

Building Wire Rope

All wire rope constructions feature design characteristic tradeoffs. In most cases, a wire rope cannot increase both fatigue resistance and abrasion resistance. Increasing the fatigue resistance by selecting a wire rope with more wires will also provide a product that has less abrasion resistance because of its greater number of smaller outer wires. When a wire rope with greater abrasion resistance is needed, one choice is a construction with fewer (and larger) outer wires to reduce the effects of surface wear. This means the wire rope's fatigue resistance will decrease. Specifications for wire rope are no different than any other machine and all operating conditions and rope characteristics must be considered. Figures 1, 2, and 3 below show the most common wire rope constructions in the 19 wire class used on heavy movable structures.

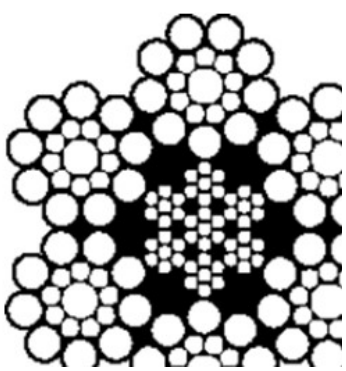
Figure 1. 6X19

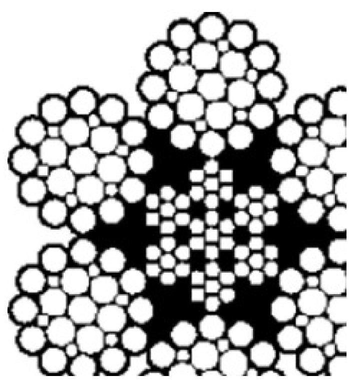
Figure 2. 6X25

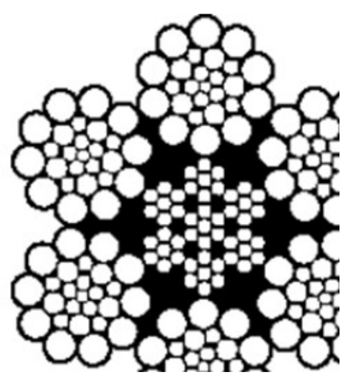
Figure 3. 6X26

The manufacturing of wire rope begins by stranding individual wires around a "center" wire in a specified pattern. The wires come together in one or more layers to form a strand. The outer strands of the wire rope are then closed around a core. Two types of cores are available, Fiber Core (FC) and an Independent Wire Rope Core (IWRC). The fibers making up a fiber core are typically polypropylene but other materials are also available for strength or historical preservation. The IWRC is exactly as defined by the acronym, an independent wire rope that serves as the core of the product. The ability of the core to support the outer strands will significantly affect the performance of the rope and the remaining strength. The purpose of the core is to provide support for the outer strands and maintain clearances between the strands while the wire rope bends during operation. The grade of the finished rope also contributes to the performance of the rope and the design factor the product will operate at. The standard grade wire rope available today is Extra Improved Plow steel, this is denoted as EIP or XIP. Higher grade ropes are becoming more common and readily available with advanced manufacturing processes and different constructions being offered. The basic characteristics of the wire rope design will limit the amount of breaking force that can be obtained for a given diameter.

The wires used in the production of wire rope are controlled by the applicable industry standards. Per ASTM A1023, Standard Specification for the Production of Carbon Steel Wire Rope, the minimum and maximum tensile strength of the wire consumed in the production of wire rope are specified. The individual wire tensile strength is based on the required rope grade to be produced and specified for the application. All wire production must follow the applicable standards to ensure the quality and consistency is not affected. Deviating from the standards should be done with caution as base wire products are critical in the life and safety of the product. Table 1 below lists the wire tensile strength grade for standard rope grades.

Individual Wire Tensile Strength Grades				
	Wire Tensile Strength Grade / Level			
Rope Grade	Minimum		Maximum	
IPS	Level 2 /	1570	Level 4 /	1960
EIP	Level 3 /	1770	Level 5 /	2160
EEIP	Level 4 /	1960	Level 5 /	2160

Table 1. Wire Tensile Strength

The minimum and maximum levels of wire tensile strength will determine the final grade of the wire rope. The design characteristics of the wire rope, such as metallic area and rope lay, can be used to increase the wire rope strength but there are limitations and outcomes that must be discussed with the manufacturer. The standard 6 strand wire rope construction with an independent wire rope core can achieve typical rope grade strengths up to EEIP. Beyond that rope grade issues become apparent due to the limitations that exist with cold working carbon steel.

The stranding and closing operations of the wire rope fabrication have changed with improved methods of forming and compaction during the stranding process. The ability to compact individual strands of the wire rope improves the tensile strength, fatigue life, and dependability. Internal fatigue testing performed on wire ropes with compacted and standard strand construction showed the fatigue life of the wire rope can be increased by as much as 45%. The compacting process reduces the diameter of the strand which increases the metallic area. This process can be carried out by swaging, rolling, or drawing the product. All of these methods add cold work to the outer wires. Figure 4 shows a 6x26WS wire rope construction with compacted strands in the wire rope and the IWRC.

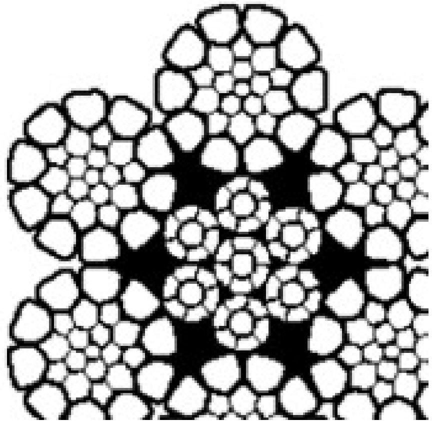

Figure 4. Compacted Strand Wire Rope

The increased surface area of a wire rope with compacted strands is shown below. The comparison of the contact points of a standard 6 x 26 WS in Figure 5 and compacted strands in Figure 6 show the reduced contacted points between the outer strands. This reduces internal friction and wear by distributing the stresses over the larger bearing surface. The same comparison can be seen with the wire rope constructions when operating on sheaves and drums.

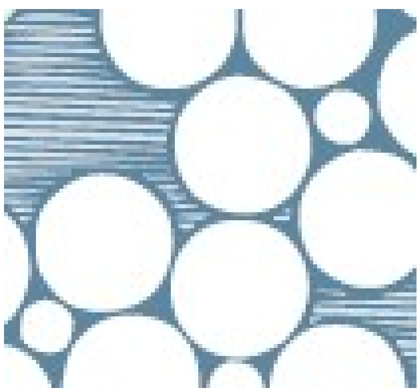

Figure 5. Standard wire rope

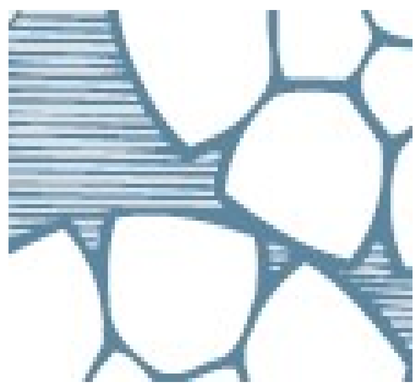

Figure 6. Compacted Strands

Corrosion Protection of Wire

The corrosion of the infrastructure is one of the most discussed topics in the bridge industry today. Corrosion of steel is an electromechanical process that occurs when there is a different electrical potential between two points connected by an electrolyte. The most effective method to overcome this destructive process is to galvanize the steel wires forming a protective zinc layer that is alloyed with the steel surface. The galvanizing process protects the steel by removing it from the external agents while the zinc becomes the sacrificial agent.

The majority of the wire supplied for use in exterior applications is galvanized with traditional high grade zinc production by the hot dip method. This process requires the wire to be submerged in molten zinc providing a very uniform coating with an aesthetically pleasing appearance. This method deposits large amounts of zinc onto the surface of the wire to protect the steel with sacrificial anodes. This coating is also applied to the surface of the wire by the hot-dip method and is included in the ASTM A1023 standard. Figures 7 below shows the traditional Zinc coating on the surface of the steel wire.

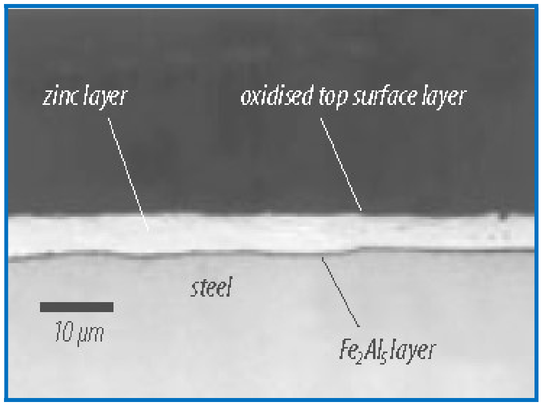

Figure 7. Zinc Coating

A testing program from US Steel compared the bending fatigue results of ungalvanized and galvanized wire ropes until the achievement of the discard criteria and until break of the rope shows that galvanized ropes reach more bending cycles. This is based on the ability of zinc coating offers better “emergency operating features” when the rope is not lubricated anymore and protects the rope from friction corrosion. In these studies the quality of the zinc was critical. High grade zinc that has removed impurities is key is ensuring the zinc layer forms correctly and uniformly with the steel surface.

Lubrication

A heavy accumulation of grease lubrication on the wire rope systems will result in water entrapment and accelerated corrosion. Heavy lubricants also limit the visual inspection of the wire rope due to the coating. Quality lubricants that bond with the steel eliminate the need for heavy grease type products providing a cleaner rope system for operation and inspection. This is also a major factor for compacted ropes since the compacting process actually reduces the areas and voids were excess amounts of lubrication would be present to protect the wire surfaces. The ability of the lubricant to bond with the wire surface is critical in this application.

Wire rope is lubricated during the manufacture so that the strands, as well as the individual wires in the strands, may move and adjust as the rope moves and bends. However this lubrication will not last the entire life requiring periodic lubrication to ensure proper performance. The lubrication applied should be light bodied enough to penetrate to the rope’s core. Lubrication can normally be applied by using one of three methods; drip, spray, or brush. In all cases it should be applied at a place where the rope is bending such as around a sheave. It is recommended to be applied at the top of the bend because that is where the rope’s strands are spread by bending and more easily penetrated. The service life of the rope will be directly proportional to the effectiveness of the lubrication method and the amount of lube reaching the rope’s working parts. A proper lubricant must reduce friction, protect against corrosion, and adhere to every wire. It should also be pliable and not crack or separate when cold and yet it should not drip when warm. The influence of lubrication and re-lubrication on the service life of the rope is illustrated in Figure 8. There is a clear benefit to properly maintaining the wire rope.

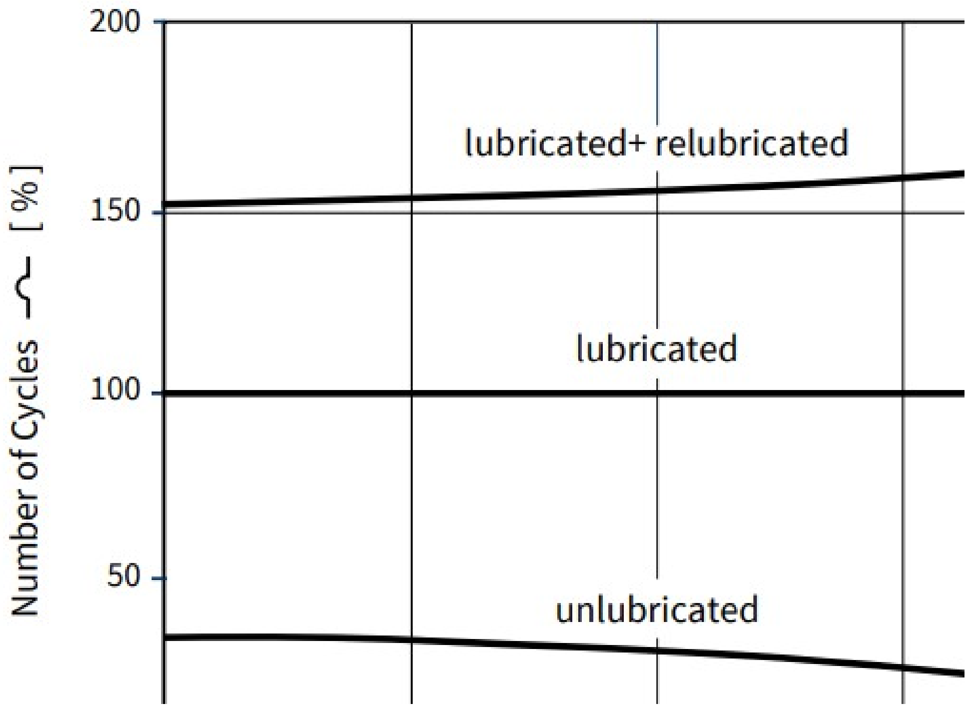

Figure 8. Performance of lubricated wire rope.

Inspection and Maintenance

The inspection of wire ropes in service is critical in evaluating the serviceability and life of the wire rope. Visual inspections are the easiest to perform but depending on the condition of the ropes this may not be feasible. Heavy lubricants are typically applied to the operating ropes concealing the surface of the rope. The cleaning of the ropes to provide a visible surface may require expensive and time consuming processes. The disposal of this material may also require the handling of hazardous waste. In the case of most vertical lift bridges this operation must be performed over a waterway. Therefore it is recommended to have the ropes electromagnetic inspected to evaluate the condition prior to the removal of coatings.

The retirement criteria of wire rope is mandated and provided by various agencies including the mining industry, ski industry, various States and Provinces in Canada, and other governmental agencies; OSHA, MSHA. The most widely used retirement criteria for wire rope is CFR 30 Part 75 (Code of Federal Regulations) which is associated with mining hoist ropes and may be used for other wire rope applications.

75.1434 Retirement Criteria:
Unless damage or deterioration is removed by cutoff, wire ropes shall be removed from service when any of the following conditions occur:

1. The number of broken wires within a rope lay length, excluding filler wires, exceeds either –
    a. 5% of the total number of wires
    b. 15% of the total number of wires within any strand
2. On a regular wire rope lay, more than one broken wire in the valley between strands in one rope lay length.

3. A loss of more than one-third of the original diameter of the outer wires.
4. Rope deterioration from corrosion.
5. Distortion of the rope structure.
6. Heat damage from any source.
7. Diameter reduction due to wear that exceeds 6% of the baseline diameter measurement.
8. Loss of more than 10% of the rope strength as determined by non-destructive testing.
9. End Terminations
    a. More than one broken wire at an attachment
    b. Improper installation of an attachment
    c. Slippage at an attachment
    d. Evidence of deterioration from corrosion at an attachment.

The Code of Federal Regulation requirements for wire rope inspection state that at least once every fourteen calendar days: *"Each wire rope in service shall be visually examined along its entire active length for visible structural damage, corrosion, and improper lubrication or dressing. In addition, visual examination for wear and broken wires shall be made at stress points, including the area near attachments, where the rope rests on sheaves, where the rope leaves the drum, at drum crossovers, and at change-of-layer regions."* When any visible condition that results in a reduction of rope strength is present, the affected portion of the rope shall be examined on a daily basis going forward.

Record keeping and notification of the conditions are important to ensure wire rope conditions do not go unnoticed. At the completion of each examination the person or agency making the examination should certify, by signature and date, that the examination has been completed. If any condition listed above is present, the person conducting the examination shall make a record of the condition and the date. Certifications and records of examinations shall be retained until the rope is retired from service.

Conclusion

The success of the system design requires understanding the characteristics of each component in a rope. This paper is by no means a complete analysis of wire rope constructions used for heavy movable structures. This paper was written to educate the bridge engineering community on the developments in the field of rope technology. The current ASTM and Industry specifications covering these types of cables allows the manufacturer the latitude to produce cables without restrictive manufacturing parameters. Innovative materials are now available to increase the corrosion resistance of the cable and greatly increase the life cycle of the products. These products can be shown to provide a significant return on investment as the products discussed in the paper will increase the costs of the components when compared to traditional steel items.

References

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