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# Tensile strength components and design considerations

A wide number of cable applications demand that the cable survive high tensile loading. Towed Remote Operated Underwater Vehicles ROVs and TUVs may require that the umbilical or tether cable provide for the bi-directional electrical and signal path as well as the instrument for towing the vehicle thru the water. Many new applications rely on optical fibers for their low loss and high data transmission characteristics, however optical fibers innate low elongation characteristics demands that the cable prevent the fibers from stretching, hence the need for low elongation, high tensile strength support members and constructions.

The following is a broad-brush overview of various tensile strength supplemental members and construction considerations that enable a cable to withstand tensile loads without seriously impeding the electrical performance characteristics.

**Wire / conductor consideration**: Copper wire is the most widely used conductor material for its high conductivity and good mechanical properties. An alternate conductor material consideration should include copper clad steel or low conductivity alloys that can vastly improve tensile strength characteristic of the conductors. This benefit however is off ser by the higher DC resistance of these high strength steel conductors and alloys. Copper alloy materials can provide superior conductivity over the lower cost copper clad steel wires but at what might be a significantly higher cost. If a principal design goal is to limit cable size, one should seriously consider using high strength conductors. *Refer to the "Conductors" tutorial for a comprehensive information on wire options.*

| Material | DC resistance @ 20° C OHMS/MFT | Weight LBS/MFT | Nom breaking strength | cost |
|---|---|---|---|---|
| Copper | 6.39 | 4.92 | 49 lbs. | Nominal |
| Aluminum | 10.3 | 1.5 | 25 lbs. | Lower |
| Alloy 135 | 7.06 | 4.92 | 70 lbs. | High |
| Copper Clad Steel Annealed | 16.28 | 4.51 | 70 lbs. | Moderate |
| Beryllium Copper | Very high strength alloy offers superior flex life with significant increase in DC resistance. (ask for details) | | | |
| Cadmium free Copper | Alternate high strength alloy offers superior flex life with minimal increase in DC resistance. (ask for details) | | | |
| Tinsel | Ultra long flex life, with significant increase in DC r. | | | |

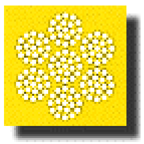
| Material | IACS % Conductivity |
|---|---|
| Silver | 105 |
| Copper | 100 |
| Gold | 70 |
| Aluminum | 61 |
| Nickel | 22 |
| Zinc | 27 |
| Brass | 28 |
| Iron | 17 |
| Tin | 15 |
| Phosphor Bronze | 15 |
| Lead | 7 |
| Nickel Aluminum Bronze | 7 |
| Steel | 3 to 15 |

**Steel rope for ground and tensile load bearing**: Where a non-critical return ground path is required an designer might consider using a high strength stainless or galvanized steel rope for that purpose. With proper placement in the cable and suitable termination or anchoring techniques the steel rope can provide a dual role.

Type of 302, 304 stainless steel is the most suitable grade for roping wire in every aspect of properties such as tensile strength, resistance to wear and fatigue etc.
Type 316 is recommended non-magnetic property or particularly high resistance to corrosion.

The following table provides breaking mechanical attributes of 7 x 19 rope construction. There are several strand configurations as well as plastic coated version that are chosen for greater flexibility, weight, elongation etc.

# Stainless & Galvanized Wire Rope



## 7 X 19

| Stainless Steel AIRCRAFT CABLE | | | Galvanized AIRCRAFT CABLE | | |
|---|---|---|---|---|---|
| Diameter (Inches) | Breaking Strength lbs. | Weight pounds M Feet | Diameter (Inches) | Breaking Strength lbs. | Weight pounds M Feet |
| 3/64 | 270 | 4.2 | 3/32* | 1000 | 16.0 |
| 1/16* | 480 | 7.5 | 1/8* | 2000 | 29.0 |
| 3/32* | 920 | 16.0 | 5/32* | 2800 | 45.0 |
| 7/64 | 1260 | 22.0 | 3/16* | 4200 | 65.0 |
| 1/8* | 1760 | 29.0 | 7/32* | 5600 | 86.0 |
| 5/32* | 2400 | 45.0 | 1/4* | 7000 | 110.0 |
| 3/16* | 3700 | 65.0 | 9/32* | 8000 | 139.0 |
| 7/32* | 5000 | 86.0 | 5/16* | 9800 | 173.0 |
| 1/4* | 6400 | 110.0 | 3/8* | 14400 | 243.0 |
| 9/32* | 7800 | 139.0 | | | |
| 5/16* | 9000 | 173.0 | | | |
| 3/8* | 12000 | 243.0 | | | |

* Available MIL-W-83420 type1 comp A

* Available MIL-W-83420 type1 comp B

**Textile cords and braids**: Probably the most familiar cable tensile member term is Kevlar® an aramid textile material. Aramid and other high tenacity fibers built into a cable significantly enhance it's load bearing properties. Kevlar - Dupont registered trademark.

The following tables provides performance characteristics of common strength members.

| Fiber type | denier | # filaments | Tensile strength | Elongation |
|---|---|---|---|---|
| Kevlar #29 | 1500 | 1000 | 75.3 lbs | 3.38% |
| Vectran HS | 1500 | 300 | 86 lbs | 3.3% |
| Technora | Similar to Kevlar #29 | | | |
| Spectra 900 | 1600 | | 95.2 | 4.4% |

¼ inch diameter double braided rope properties comparison (Pelican Rope Works)

| Rope type | Specific gravity | Break strength | Elongation | UV / Abrasion |
|---|---|---|---|---|
| Kevlar | 1.42 | 4000 lbs | 1 – 2% | Excellent |
| Spectra | .97 | 5900 lbs | 5 - 9% | Excellent / good |
| Technora | 1.39 | 4600 lbs | 4.6% | Excellent |
| Vectran | 1.4 | 4750 lbs | 1% | Excellent |
| Zylon PBO | 1.48 | 6300 lbs | 1 - 2% | Poor / Excellent |
| 7 x 19 Galv rope | 121 lbs/1Mft. | 4750 lbs | 4 – 5% | Excellent |

# Table 1: Synthetic Fiber Yarn Properties

| Material | Specific Gravity | Specific Modulus, N/tex* | Specific Strength, N/tex* | Other Characteristics |
|---|---|---|---|---|
| Nylon (polyamide) | 1.14 | 4 | 0.84 | 10-15% wet strength loss. Poor wet internal abrasion resistance. Moderate creep. |
| Polyester | 1.38 | 10 | 0.84 | Good wet internal abrasion resistance. |
| Polypropylene monofilament | 0.91 | 8 | 0.73 | Lighter than water, moderate creep, low strength. |
| Polypropylene multifilament | 0.91 | 3.5 | 0.66 | " |
| Aramid (Kevlar 29, Twaron, Technora) | 1.44 | 49 | 2.03 | Axial compression fatigue problem. |
| Aramid (Kevlar 49) | 1.44 | 78 | 2.08 | Extra high modulus. |
| HMPE (Spectra 900, Dyneema) High-Modulus Polyethylene. | 0.94-0.97 | 124 | 2.65 | Low melt point, high creep. |
| HMPE (Spectra 1000) High-Modulus Polyethylene. | 0.94-0.97 | 175 | 3.10 | Extra high modulus. High creep but less than S900. |
| LCAP (Vectran) Liquid Crystal Aromatic Polester. | 1.41 | 46 | 2.01 | New fiber. Very little creep. |
| PBO (... Dow) Polybenzoxazole. | 1.56 | 177 | 2.54 | New fiber. Very high modulus. Expensive. |
| Steel (wire) | 7.85 | 26 | 0.18 | Typical properties. Corrodes. |

- NOTES: Approximate values, actual properties may vary.The unit tex is the weight in grams of 1000 meters of material.Newton/tex = 1 MN/(kg/m) where kg/m is rope linear density.Multiply Newtons/tex by 145,400 x SG to obtain lb/in2.

Table provided by Tension Technology International

**<u>Braid vs. Cord</u>**: What is the best construction for my application?
Both methods can provide suitable tensile strength to a cable. Two considerations influence which to use.

A) The method of termination, i.e. how one anchors the strength member.
B) The type of and points of stress that are applied.

**Points for choose between braid or a cord for tensile load strengthening.**

- High tenacity fibers (HTF) provide the most tensile strength when used as a central core. The central cord will provide most of it's full tension loading support without having to first contract or constrict the underlying cable as the case with a braid. As a rule, when placed under load braided strength members will first elongate where the fiber filaments shift angles and position compressing the core, before full tensile support is achieved. This characteristic increases the effective elongation properties of the tensile member, much the same is found with braided ropes.

- HTFs wrapped at the exterior of a cable, (under the jacket) with a shallow angle provide greater tensile loading than long angle spiral wrap or braids. The fibers are applied more parallel with the conductors thus have a lower wrap angle. The designer should beware however as too shallow an angle renders the cable inflexible. HTFs drawn parallel with the cable will limit bend radius as it is spooled or drawn over sheaves or pulleys therefore is not recommended for tether or pipe inspection systems that are frequently dispensed and retrieved.

- Braid constructions offer two advantages
    - Ease of termination; being able to slip the braid cone around a connector back shell or other anchoring device. This is a user preference.
    - With thin jackets or of a high elongation compound, the HTF braid can reduce "milking" of the protective jacket assuming that the HTF braid is engaged when the cable is tugged by hand.

*<u>Application example</u>: An operator tugs the cable by hand gripping the cable by its outer jacket. This cable has a central tensile cord member and is minimally engaged with the surrounding cable components. It is possible that the surrounding conductors and jacket will be "milked" back from the HTF cord anchor resulting in wrinkles or the jacket and conductors pulling away from the connector back shell. When the cable system is towed via a respooling winch the potential for this to occur is minimal. If however the cable retrieving systems uses surface gripping pinch rollers or sheaves then there is increased risk of jacket to substrate bond separation or localized elongation of the jacket between the pinch point and any point down stream where the cable might be caught or snagged.*
*It is highly recommended that you inform your cable design consultant what method you use to retrieve the cable so they can recommend the best construction to meet your needs.*

**What else should be considered in selecting the proper fiber?**

- It is believed that under high flexure conditions, continuous flexing and working of the cable can cause the aramid fibers to fray at the braid cross over points. Vectran, an alternate material to aramid fiber, is advertised to be less susceptible to abrasion wear in braids than aramid. PBOs while having superior tensile strength, are susceptible to UV and will loose their mechanical properties is exposed to sunlight for an extended period of time. Spectra fibers specific gravity is< 1 hence is buoyant. Other differences exist between the fibers such as cut and abrasion resistance, flex fatigue, temperature range, creep, and friction coefficient.

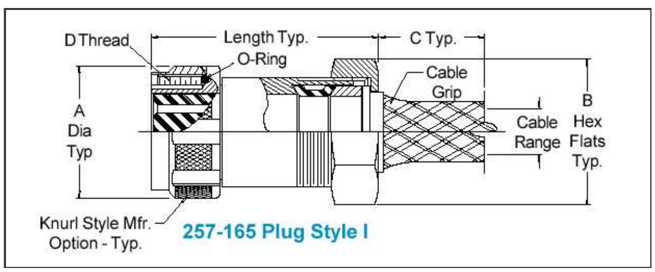
**Proper anchoring of a tensile load support member.**

To receive the full benefit of a high tensile strength cable member steps to properly anchor the braid or cord must be taken.

- Within the cable: Consult a Storm products cable design specialist to help select the material type and placement of the strength member right for your application.
    - Central cord
    - Ground lead
    - Braid
    - Jacket imbedded
    - Combination

- At the working end: Depending on the application the tenacity of the termination could vary. A robotic pipe crawler camera system may design the tensile strength of the tractor cable and the tie off load such that under no circumstances would the service provider lose the crawler inside the pipe. The cost for digging up a pipe to dislodge a robotic inspection crawler may well exceed the cost to replace one that is damaged yanking it free from a tight spot. Various wire rope rigging termination hardware can be used to accommodate quick disconnect or to provide maximum reliability.

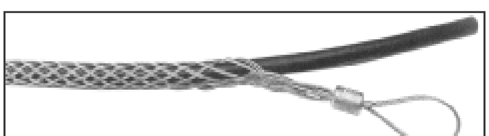
- At the connector: Utilize the anchoring instructions provided by the connector manufacturer. An method for bolstering protection against pull damage would be to employ a Kellums cable pull grip or lanyard that is secured to the faceplate of the equipment or skid.



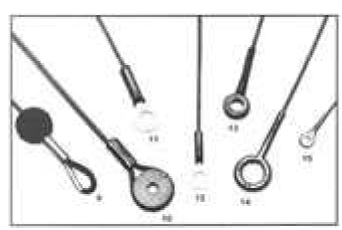

- Potted or molded back shell: If the body of the connector is to be overmolded or potted steps should be take to anchor the strength member to the connector frame. Storm Products with extensive overmolding experience can design and manufacture a molded connector body that provides superior flexure and tensile loading strain relief.

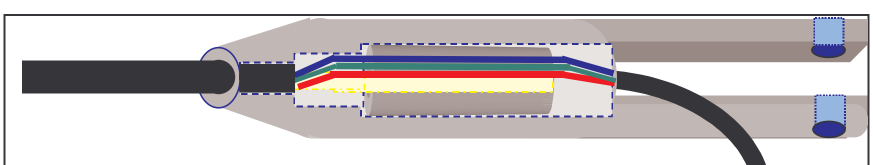
- Connector takeout anchoring: Spelter sockets or cable pulling grips can be used to secure the Skid or control equipment end of the cable.

Spelter Socket



Kellums cable grip





ROV towing shackle