OPGW Designs
"Fully Stranded" versus "Center Tube"

Introduction.

Since the 1980's there have been several OPGW design concepts. Today, the two most commonly used are:

- "Fully stranded" type, and
- "Center tube" type.

This paper will explain the design theory for each of these, and compare their advantages and disadvantages.

The Fully Stranded Type Design.

Brugg pioneered the use of stainless steel loose tubes (SSLT's) for aerial cable applications in the early 1990's. This was a quantum leap forward in OPGW design as evidenced by the fact that now every major OPGW supplier in the world has some version of a design using the SSLT. But, the use of a SSLT alone does not guarantee that a cable will have all of the advantages of Brugg's design concept.

Figure 1 shows a typical "fully stranded" Brugg-type SSLT OPGW design. In stranded SSLT designs, up to three (3) SSLT's are stranded around a center wire. (Some suppliers will use more than three SSLT's in a layer, but Brugg does not. The reason will be explained in the next section.) The center wire itself will be aluminum-clad steel (ACS) or 6201 aluminum alloy (AY) depending upon the required mechanical and electrical specifications. To complete the first layer of the cable, ACS or AY wires will be stranded with the SSLT's. Which wire type is used will again depend upon what the mechanical and electrical specifications are. Then at least one more layer of ACS or AY wire, or a combination of both, will be concentrically stranded over the first layer to complete the cable. Here too, the material used will depend upon the specifications.

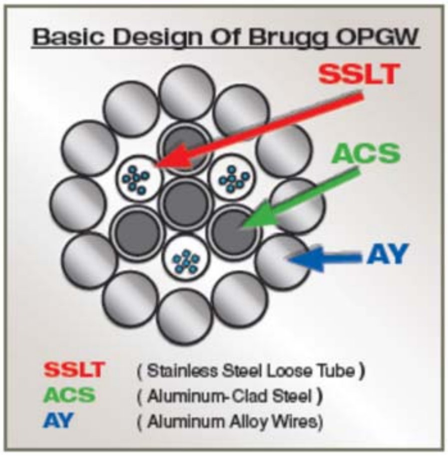

Figure 1 – A typical "fully stranded" type OPGW

Additional Elements of Brugg's Fully Stranded Type Design Concept.

While anyone can make a stranded SSLT cable that looks similar to the Brugg one in Figure 1, Brugg notes that there are two important design elements that are not apparent just from the cross-sectional depiction of the cable:

1. The wires and tubes in the first layer are arranged such that at least one wire will be on either side of each SSLT.

2. The SSLT's themselves are slightly undersized relative the wires on either side.

The combined effect of this construction is to create a structural "bridge" over the SSLT's. This protects the tubes from any crushing force on the cable, thereby directly increasing the cable's crush resistance.

In addition, Brugg uses concentric lay stranding as illustrated in Figure 2. Here in the US, conventional overhead groundwire and OPGW are left-hand lay in the outer layer. With concentric lay stranding we are able to alternate the lay direction of each layer of the cable in order to reduce torque. This also gives the cable greater flexibility. By combining this with proper wire and tube fit, conservative lay lengths, and superior wire performing, we are able to further minimize or even eliminate torque while also maximizing flexibility.

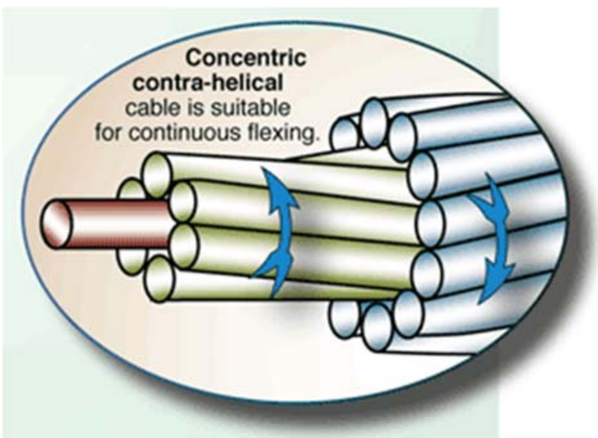

Figure 2 – Concentric lay stranding
(http://motionsystemdesign.com/system-solutions/106MSD-concentric.gif)

Helix and Fiber Strain Margin.

Stranding the SSLT's has benefits beyond just reducing torque and increasing flexibility. It is also highly beneficial to the long-term optical reliability of the cable. This is because stranding imparts a helix into the tube as shown in Figure 3. The helix in the tube effectively increases the "zero fiber strain margin" in the cable. We will explain the fiber strain margin and why it is important in detail later in this section. For the moment, just understand that because of the helix in the tube, when a tensile force is applied to the cable, the helix initially stretches open before the material itself elongates. This is illustrated in Figure 4.

When a tensile force is applied to a helix, it will begin to stretch and also its radius will decrease. See Figure 4 again. This results in a force on the center wire which imparts friction between the two elements. As the tensile force continues to increase, eventually a point is reached where the helix itself cannot stretch any further and the wires and tubes themselves begin to elongate.

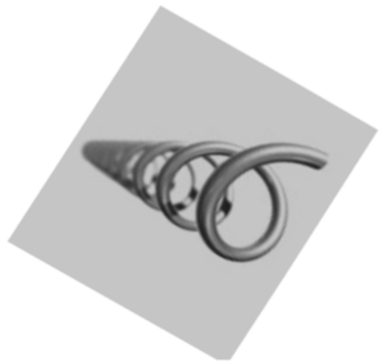

Figure 3 – The helix imparted to the SSLT’s

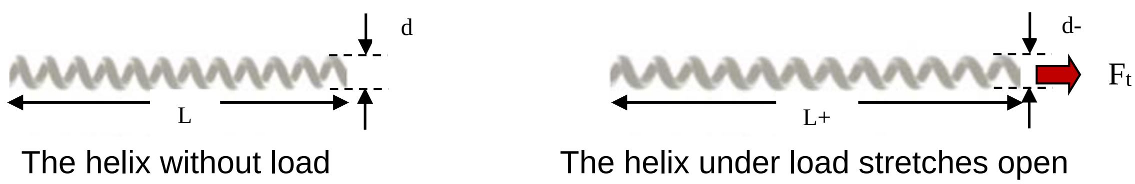

Figure 4 – How the helix responds under tension.

The amount of helix is called the “helix factor”, and it is determined by the distance that a wire or tube takes to go 360º around the center wire. This distance is known as the “lay length” and is illustrated in Figure 5. When a conservative value for lay length is used, the helix factor will be around 2.5%. That is, the wire or tube will be about 2.5% longer than the unit length of the cable itself along its neutral axis. See Figure 5 again. Accordingly, if the helix factor is 2.5% and there is 1 ft of cable, then the tubes and wires around the center wire actually will be 1.025 ft long.

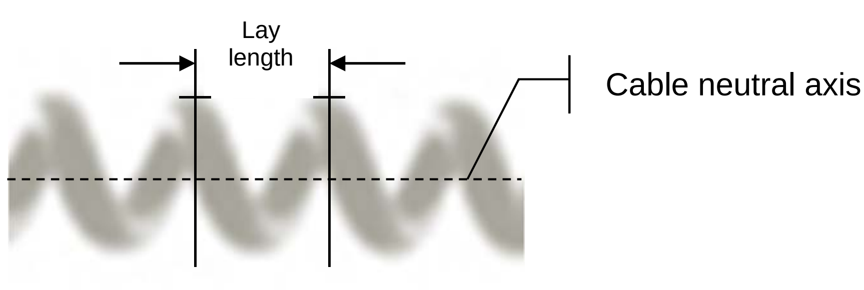

Figure 5 – Lay length

In cables made with a conservative lay length, when a tensile force reaches an amount equal to about 60% RBS (rated breaking strength) the helix will reach the point where it cannot stretch itself open any further and therefore its materials, that is the wires and tubes, will themselves begin to elongate.

Since the materials themselves will only begin to elongate when a tensile force greater than 60% RBS is applied, it follows that until that point, the fibers themselves will not experience any of the applied force. This is the basis for fiber strain margin which we can now define:

Zero Fiber Strain Margin = the difference between a tensile force applied to a cable and the point at which the fibers actually experience a tensile force

So, if the tube material does not begin to elongate until 60% RBS, the zero fiber strain margin (or just “fiber strain margin”) is at least 60% RBS. However, actually the fibers still will not experience any force because of “excess fiber” inside the loose buffer tubes.

“Excess Fiber” or “Fiber Overlength” in Loose Tubes.

In loose buffer tubes, regardless of whether they are made out of plastic or stainless steel, the fibers are suspended in gel that floods the inside the tube. This leaves the fibers free to move in response to changes elongation that will result from variations in tension, temperature and loading conditions. Moreover, the fibers are laid inside the tube in a sinusoidal shape. See Figure 6.

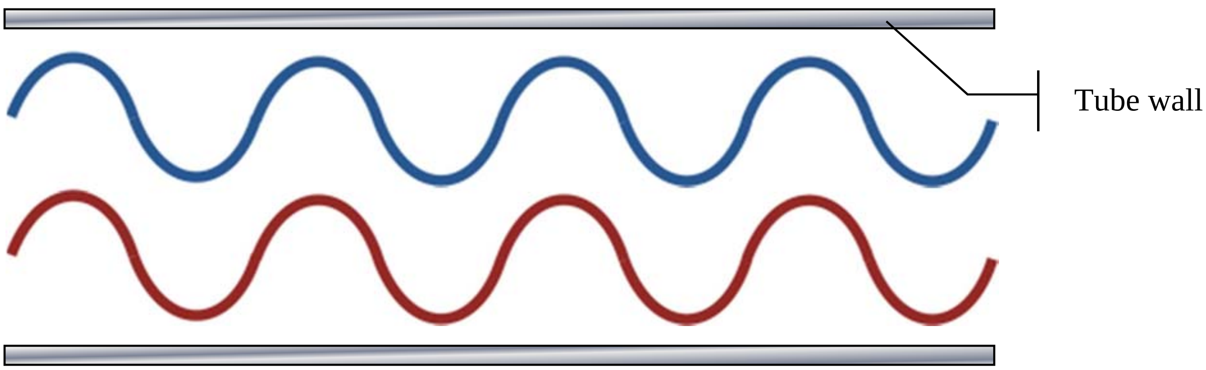

Figure 6 – Fibers inside a loose tube

Just as the helix resulted in the wires and tubes being longer than the cable itself, the sinusoidal shape of the fibers in the tube results in there being slightly more fiber per unit length of tube. In other words, if there is 1 ft of tube, there will be 1+ ft of fiber. This is referred to as “excess fiber length” or “fiber overlength.” The amount of fiber overlength is about 0.05% in most loose tubes.

Furthermore, just as the helix caused there to be a fiber strain margin, the excess fiber or fiber overlength further adds to the fiber strain margin. This is because after the helix has been stretched to its limit, then an applied tensile force will cause the tube itself to elongate. However, initially the fibers respond by straightening out. It is not until the sinusoidal shape has been completely take out and the fibers are actually straight that they begin to experience the applied tensile force. In a typical cable, the fiber overlength will increase the fiber strain margin by an amount equal to about 20% RBS.

Total Fiber Strain Margin.

We have seen that there is zero fiber strain margin from the helix in the stranded tubes and from the excess fiber within the tubes. The total zero fiber strain margin is then the combination of these two. *In a typical Brugg design, this margin will be equal to 80% RBS or more.*

Why Strain Margin Is Important to Long-Term Reliability.

Fiber strain margin is important for long-term reliability. The reason is because of the nature of optical fibers, especially when subjected to mechanical stress. While optical fiber is very strong (100 kpsi is the norm), it is nevertheless glass and therefore somewhat brittle. Also, there can be microscopic imperfections in a fiber’s core or cladding, or minute damage after drawing from the subsequent coloring and processing during tube fabrication and cabling.

Initially, there will be no evidence of such imperfections or damage whatsoever. These could only be detected under extreme magnification. Optically, the fiber will perform to all specifications. However, when a fiber is subjected to mechanical stress, over time any such flaws can become cracks which, like a chip in a car windshield, can propagate and cause the fiber to show increased attenuation and eventually to break completely.

When there is no mechanical stress, as when any tensile force is below the fiber strain margin, any such flaws are inconsequential. Or, as we prefer to say:

No strain = No problem.

Summary of Features and Benefits of a Brugg Fully Stranded Design.

The advantages of a fully stranded Brugg OPGW are:

1. **Torque balance.** Brugg’s fully stranded stainless steel loose tube (SSLT) designs minimize torque which means that they can be strung without using a “gator” or “monkey tail” anti-rotation device (ARD) which makes stringing faster, safer, and hassle-free. And, saving time means saving money too.

2. **Greater flexibility and crush resistance.** Brugg’s fully stranded SSLT designs have superior flexibility and crush resistance which means they can pulled greater distances, through more angles, and using smaller stringing blocks. This in turn can mean fewer splice points. This feature too can save time and money. In addition, reducing splice points may help improve an optical link.

3. **Higher fiber strain margin**. Brugg’s fully stranded SSLT designs have a zero fiber strain margin equal to 80% RBS or more. This means that the fibers will never actually experience any of the tension on the cable itself during even the most severe design load conditions used today. This thereby means greater long-term optical reliability. In other words, the fibers will not end up going dark or showing increasing attenuation or PMD.

The Center-Tube Type Design.

The center-tube type design was one of the first OPGW design concepts. Today there are several versions of them being used. See Figure 7. Many of the first generation center-tube type designs used a “tight buffer” where the fibers are fixed inside the buffer tube. See Figure 8. Tight buffers are no longer used in aerial cables such as OPGW and ADSS, but are still used in many indoor type fiber optic cables. Loose tube construction is now used for aerial cables.

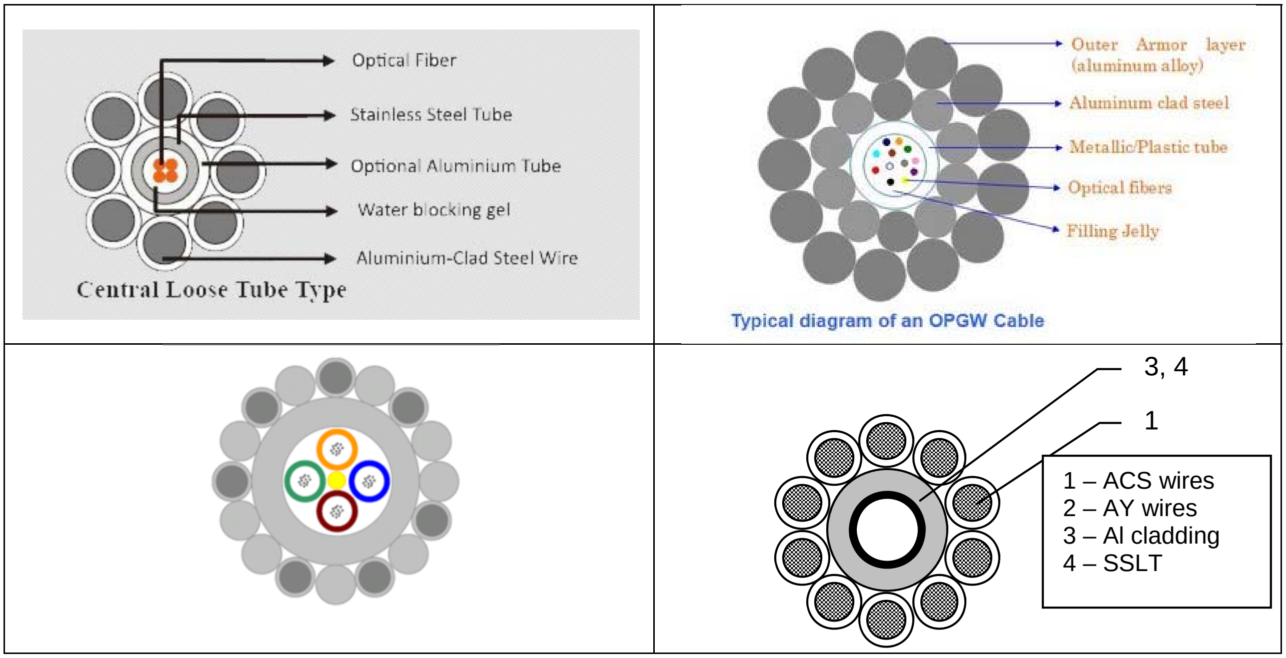

Figure 7 – Various center-tube type designs.

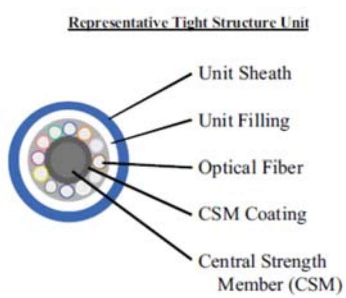

Figure 8 – A typical tight buffer tube.

In all center-tube type designs the optical unit of the cable is the center element. In some, the center element is a SSLT. In others, it is a SSLT or a plastic loose tube inside an aluminum pipe or tube, or with aluminum directly extruded onto the SSLT. In yet others, multiple plastic loose tubes are stranded around a fiberglass reinforced plastic (FRP) strength member and then placed inside an aluminum pipe or tube. Sometimes the buffer tubes are also wrapped with water blocking or heat resistant tape. When an aluminum pipe or tube is used, it may be welded or extruded.

Better Use of Available Area.

Center tube construction does make better use of the cross-sectional area of the cable for a given diameter. Also, the aluminum pipe, tube, or cladding is usually similar to the high conductivity 1350 aluminum used in bare overhead electrical conductor. For these reasons, center tube type designs generally have mechanical and electrical specifications that can make them look quite attractive. These designs are often less expensive to manufacture as well.

An Important Trade-Off: Optical Performance.

While center tube designs do have good mechanical and electrical specifications, there are some drawbacks. The large center optical unit is inherently less flexible and more susceptible to damage from crushing or torsion forces. For this reason, they nearly always have to be installed using larger stringing blocks and with the use of an anti-rotation device (ARD or “gator” or “monkey tail”). There are often other stringing restrictions as well that effectively limit the pulling distances and complicate installation.

Of even greater importance than these limitations though is the fact that center tube designs inherently have lower fiber strain margin. When there is just a single tube, the fibers have no helix. The only source of strain margin is the excess fiber in the tube itself. Even when multiple tubes are used, the geometry is still such that the helix factor is greatly reduced. Lower fiber strain margin means that the fibers may experience tension under some conditions, and in turn this may compromise long-term reliability.

Enhancing Performance.

Brugg does offer center-tube designs. Our Centro™ cables feature a center SSLT, and our Centro-AL™ ones feature an aluminum clad SSLT. In contrast to other designs where a tube or tubes are merely inserted into an aluminum pipe, with our integrated construction, the entire optical unit will expand and contract together. This thereby eliminates anomalies such as “suck back” that can be long-term problems. We also increase the sinusoidal shape of the fibers in the tube in order to increase excess fiber. In doing so, we achieve a fiber strain margin equal to 50% RBS or more. We also adjust the lay length of the outer wires and other manufacturing parameters in order to minimize torque, but we still must require an ARD for pulls over 15,000 ft.

Guidelines for Using Each Design Concept.

There is an old saying to the effect of “The right tool for the right job.” This philosophy applies to using the fully stranded and center-tube type designs.

Fully Stranded. Best for:

- All new construction.
- When ruling spans are greater than 800 ft.
- For river crossings and similar situations that place high demand on the cable’s optical unit.
- When splice points are expected to be located more than 15,000 ft apart.

- When a line has a large number of angles to pull through.

Center-Tube. Best for:

- For existing lines, especially very old ones, that were designed using conventional groundwire such as 3/8” HS or EHS or 7#8 ACS or similar ACS cables.
- When ruling spans are relatively short.
- When economy and not long-term performance is important.

Questions? Need additional information? Please contact Brugg’s project engineering at 706-235-8755.