The last couple of articles have delved pretty deep into concepts of technology used to improve performance of wired and wireless technologies. In this article we'll take a step back and focus on some physical attributes of fiber-optic construction.

If you’re new to the fiber-optic world fear not; it’s about to get explained at a basic level. We’ll steer clear of anything too deep (except maybe the fiber that’s being buried).

Fiber generally gets constructed in one of two places; on poles (aerial), or is placed underground either directly buried or inside a flexible plastic pipe called innerduct. There are a few exceptions that we will not cover in this article such as seafloors or interior fiber. For the purpose of this article, we will focus on your average everyday materials and construction methods used to install those materials towards a working underground fiber network in the outside environment.

**FIBER-OPTIC CABLES**

There are a wide variety of fiber cables in the world and I’ll do my best to break down what you need to know about them. Generally, the same cable can be used for underground as can be used for aerial. The most often-used fiber cable for outside plant is referred to as loose-tube. During product selection it is important to choose a cable you can use throughout the project because switching from one cable to another requires those cables to be spliced together. This results in a minor loss in signal quality as well as added parts and pieces required to secure and house that splice point. If that splice is in an underground location, a vault will need to be installed – that could add $800 or more (depending on size and quality specified) to the cost. For the purpose of outside construction we will focus on loose-tube fiber.

Fiber strands are individually color-coded. If more than 12 strands of fiber are in a cable, the buffer tubes provide a color scheme to keep strands organized since there will multiple strands of fiber using the same color. Four red strands exist in a 48 strand fiber cable; each of those red strands will be in a different colored buffer tube. And that’s how you keep track of all those strands!

<table>
<thead>
<tr>
<th>Strand</th>
<th>Color</th>
<th>Strand</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Blue</td>
<td>7</td>
<td>Red</td>
</tr>
<tr>
<td>2</td>
<td>Orange</td>
<td>8</td>
<td>Black</td>
</tr>
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<td>3</td>
<td>Green</td>
<td>9</td>
<td>Yellow</td>
</tr>
<tr>
<td>4</td>
<td>Brown</td>
<td>10</td>
<td>Violet</td>
</tr>
<tr>
<td>5</td>
<td>Slate</td>
<td>11</td>
<td>Rose</td>
</tr>
<tr>
<td>6</td>
<td>White</td>
<td>12</td>
<td>Aqua</td>
</tr>
</tbody>
</table>
**Loose-Tube Fiber Material**

Below is a diagram that depicts the common materials inside a fiber-optic cable. The diagram below is an armored cable and has steel wire encompassing the entire cable. Dielectric cable would not have this armor but the rest of the cable would look the same.

![Diagram of Fiber Optic Cable](image)

**Armor:** A series of steel wires wrapped around the cable to offer added protection. This type of cable works very well in areas with high concentrations of squirrels that like chewing on cables! You can also transmit locate signals through this armor since it is metal (nothing else in the cable is).

**Fiber Strand:** This is the stuff you’re interested in – a hair-thin piece of glass that carries the light down the cable. The glass is encased in a cladding that keeps the light confined within the fiber strand itself.

**Strength Member:** Because fiber is somewhat fragile and is often pulled into innerduct (and pulled somewhat in aerial), a strength member is built in to take most of that stress.

**Buffer Tube:** Buffer tubes encase 12 strands of fiber. Each fiber strand has its own color and each buffer tube has its own color. This allows installers to know which connections belong where.
**Gel:** Gel is used to provide water ingress protection as well as stress “cushion”. Should areas around the cable come under stress from things like freezing ice; the gel provides a flexible gap to help prevent the fiber from becoming pinched.

**Outer Jacket:** The outer jacket is made of PVC and is the front line defense against the elements.

**Rip Cord:** The rip cord is used by the fiber splicer to cut through the PVC jacket. You never want to use a sharp tool to cut into the cable to remove the jacket. Pulling the ripcord provides a safer method of accomplishing this.

Note: A 10AWG copper wire (called a tracer wire) needs to be installed with the innerduct if you choose to use dielectric cable since there is nothing conductive in a dielectric cable.

**UNDERGROUND FIBER MATERIALS**

Underground construction requires the use a completely different array of products as compared to aerial. The process of engineering is also quite different. Although the fiber is generally better protected underground, it is not fool-proof. Because the fiber is buried it is susceptible to being damaged from homeowners, farmers, construction crews, etc. Basically anyone that digs and fails to call Digger’s Hotline to have utilities properly marked.

### Innerduct

Innerduct, usually made of High Density Polyethylene (HPDE), is used in both boring and plowing construction methods. Boring involves a machine that can drill into the soil and traverse horizontal to the earth’s surface...the direction of drilling can be controlled. Plowing is a method of using a large vibrating blade that creates a large groove in ground – enough to push the innerduct into that opening.

Telecommunications innerduct is usually orange, power is red, and gas is yellow. This is the same set of colors used when utility locators spray paint on the streets, grass, and sidewalk to let others know where those utilities are. Innerduct comes in a variety of sizes to suit the needs of the project. The most common sizes for fiber projects are 1 ¼” and 2”. If more cables are required or if future plans require more cables, they make 3”, 4”, and larger.

### Vaults

Vaults are essentially durable boxes installed flush to ground level where the innerduct, and fiber enters and exits. These vaults are usually made of polymer concrete or fiberglass. The polymer/concrete ones are used in locations where vehicles or other heavy objects might run over them. Load ratings for vaults are referred to as “Tier” and have a design load rating and a test load rating that is 50% higher that the vault must pass to qualify for certification at that Tier rating.

<table>
<thead>
<tr>
<th>Tier Rating</th>
<th>Design Load (lbs)</th>
<th>Test Load (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier 8</td>
<td>8,000</td>
<td>12,000</td>
</tr>
<tr>
<td>Tier 10</td>
<td>10,000</td>
<td>15,000</td>
</tr>
<tr>
<td>Tier 15</td>
<td>15,000</td>
<td>22,500</td>
</tr>
<tr>
<td>Tier 22</td>
<td>22,500</td>
<td>33,750</td>
</tr>
</tbody>
</table>
Where a vault is located and what’s inside depends on the design needs. Often times there is simply a length of fiber coiled up inside. If the fiber is splitting into multiple directions or if that was the location where the reel of fiber ran out, there will be a fiber splice enclosure inside. This enclosure will have the ends of the cables inside where the fiber strands are carefully spliced together and secured. Enclosures have a gasket around the entire unit to keep water from entering. In some cases, a ground rod may also be inside for tracer wire.

**UNDERGROUND FIBER CONSTRUCTION METHODS**

The two most common methods, as mentioned above, include boring and plowing. Each has its’ benefits depending on the situation. Both methods can be used in the same job, so choosing the right method can save money so long as you know the soil properties and existing utility circumstances.

**Horizontal Directional Boring**

Boring is great for urban environments but can only install innerduct. The reason for this is that the drilling operation ends at a location where the innerduct is attached to the drilling hardware – then the innerduct is pulled into the soil and back to the boring machine. You can’t pull the fiber back because the pull would put too much stress on the cable (tension and scraping against rocks) and makes it impossible for fiber to be directly pulled into the ground using the boring method. It’s for this reason that boring always involves innerduct.

The primary downside to boring is cost. Boring machines go a little slower and being in urban environments requires the operators to physically expose any utilities they are crossing. Sometimes these utilities are under sidewalks or some other hard surface which requires coring a hole through it or removing parts of the hard surface. Another aspect of boring is the cost to purchase and operate the equipment. The boring bits (the part that does the drilling) can be expensive – and bits capable of boring through rock are very expensive.

**Plowing**

Plowing is less expensive and can put both innerduct and fiber directly into the ground. Because the operation can move along faster, the cost is less per foot when compared to boring. There are some downsides to plowing however.

First, it requires the machine to drive over the entire construction path. In some cases this is not possible; very wet marshes, rivers, lakes, or environmentally sensitive areas may prevent plowing to be an option. Plowing also disturbs the soil more, and although it’s normally not a problem, it still doesn’t compare to boring. Plowing also doesn’t work in urban environments where hard surfaces exists – roads, sidewalks, and rock cannot be plowed.

**Trenching**

Trenching is like a chainsaw for the earth (for lack of a better description). Trenching works well for small jobs or confined spaces where it may be difficult for a plow to access. Trenching also causes the most disturbance to the ground and requires moderate restoration since the trench needs to be filled when the work is done. Trenching machines come in a vast variety of sizes from personal sized all the way to massive units capable of making a trench large enough for trans-continental pipelines.

**Hand Digging**

Hand digging is self-explanatory. At times, construction requires the hand digging around sensitive utilities or upon approach to a building. In reality you can only get so close to a building with machines until the shovels have to come out.
FIBER MARKERS AND TRACER WIRE

There are several types of markers, each of which have their purpose. All markers should have contact information listed on them and have orange on them to indicate that it is for telecommunication.

The first, and simplest, is a flat station marker that sticks in the ground. A very inexpensive solution that gets the job done. These are not used often because they lack durability over the long-term compared to other markers.

Probably the most common fiber-optic marker is called a “dome” or “round” style. It is cylindrical in shape, white in color, with an orange dome on the top (or entirely orange). These tend to have decent durability. A similar product to the round style is the triangular style that accomplished the same goal.

A relative to the round and triangular styles is the test station. It looks the same but has a removable cap at the top of the marker where transmitters can be connected to metallic posts. The posts are bonded to the tracer wire (often times 10AWG copper wire). The transmitted signal is connected to the tracer wire which is ultimately grounded. A locator can be used to follow the route of the cable by detecting the signal emanating from the tracer wire until it reaches earth ground.

FINAL THOUGHTS…

Planning underground fiber requires a firm understanding of what’s in the ground as well as what’s on the surface. Knowing these specifics allows you to decide which construction method and materials are required to successfully build a great fiber-optic system.