Development of Wrapping Tube Cable with Spider Web Ribbon using fiber based on ITU-T G652 D

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Abstract
In 62nd IWCS, we have reported Ultra-High Density Wrapping Tube Cables (WTC) with innovative optical fiber Ribbon, called Spider Web Ribbon (SWR) [1]. In this time, we have successfully developed new WTC extending fiber counts up to 1728 fiber using SWR and applying new bending insensitive fibers which are compatible to the conventional ITU-T G652 D fiber network. This cable shows excellent mechanical and environmental characteristics, which are comparable to those of ITU-T G657 A1. In this paper, we will describe the design concept of new cable and new fiber, and performance of the trial cable.

Keywords: optical fiber cable; Spider Web Ribbon; Wrapping Tube Cable; ITU-T G652 D fiber

1. Introduction
In recent years, the demand for broadband services using optical access networks has grown explosively. As the majority of CAPEX of network deployment normally comes from construction cost, faster and economical deployment of optical cables contributes to the reduction of total CAPEX for an operator. Some of the solutions to achieve faster and economical deployment are to introduce SWR&WTC which has been reported in 62nd IWCS. First, SWR&WTC enables mass fusion splicing for faster installation. In addition, small diameter of this cable efficiently increases the fiber counts per conduit. Smaller cable also allows to be wound on a drum with longer length, thus reducing the number of splicing points over a span and reducing the splicing and closure setup cost, and effectively utilizing existing facilities such as underground ducts or telephone poles. Furthermore, WTC is full dry structure. Introducing full dry cable is another solution to reduce the installation time by eliminating the process to wipe out jelly from fibers.

We have designed WTC with SWR using fiber of having small Mode Field Diameter (MFD) due to getting bending insensitive as G657 A1 fiber.

However, when splicing fiber having MFD comparable to ITU-T G657 A1 fiber with existing G652 D fiber, OTDR step gainer or exaggerated loss due to the difference of MFD of these fibers appears in a uni-directional OTDR trace, which may lead misunderstanding of splice loss for installers. If G652 D fiber can be applied to WTC, such misinterpretation should not be occurred.

2. Cable Design
2.1 The design of bend insensitive fiber
We have designed a new fiber optimizing macro bending and micro bending characteristics.

2.1.1 The design of macro bending characteristic
Table 1 shows design of the three types of fiber. In general, in order to improve macro bending characteristic, it is better to make Mode Field Diameter (MFD) smaller. However, some misunderstandings may appear in case of splice between smaller MFD fiber and G652 D fiber for installers if splice loss is measured by uni-directional OTDR. In this time, we have designed the new fiber having MFD equal to Type X fiber and bending loss equal to Type Y in order to solve this issue.

Table 1 Design of the new fiber

<table>
<thead>
<tr>
<th>Fiber Type</th>
<th>X</th>
<th>Y</th>
<th>New fiber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macro bend</td>
<td>R30</td>
<td>R15</td>
<td>R10</td>
</tr>
<tr>
<td>loss</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MFD</td>
<td>9.2 ±0.4</td>
<td>8.6 ±0.4</td>
<td>9.2 ±0.4</td>
</tr>
</tbody>
</table>

2.1.2 The design of micro bend characteristic
In order to improve micro bending characteristics of the above new fiber, we have designed the parameter of the new fiber coated resins, ‘Kcoat’ [2]. ‘Kcoat’ indicates micro bending sensitivity calculated by formula (1) and it is known that smaller ‘Kcoat’ makes micro bending characteristics better. The formula (1) shows that it is important for ‘Kcoat’ to adjust parameters of primary and secondary coating such as thickness, Young’s modulus and stiffness.

\[
\Phi_{\text{bend}} \propto K_{\text{coat}} = \frac{(E_p/t_p)^2}{H_0^2 H_{0.25}^2 0.125 H_0^2 + R_s^2 E_s} [\frac{125.0 - 25.0}{3^3}]^1.125 - 0.25p
\]  

\(\Phi\): micro bending characteristics  
\(E_p\): Young’s modulus of Primary coating  
\(t_p\): Thickness of the Primary coating  
\(E_s\): Young’s modulus of Secondary coating  
\(t_s\): Thickness of the Secondary coating  
\(R_s\): Outer diameter of secondary coating  
\(H_0\): Stiffness of glass fiber  
\(H_s\): Stiffness of Secondary coating

We have investigated some combinations of fibers and coating resins to search optimum fiber design. Table 2 shows the combination of several fiber types, and coating resins. Figure 1 shows the relation between the combination and micro bending loss sensitivity. The micro bending sensitivities of these manufactured fibers were evaluated as per IEC TR62221, Method B, and fixed diameter drum test. In this test, the fiber specimen is wound around the drum coated with 380 grit sandpaper, and the attenuation of the fiber is measured at the wavelength of 1550nm.

Table 2. Combination of fibers and resins

<table>
<thead>
<tr>
<th>Type</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber</td>
<td>Type X</td>
<td>Type Y</td>
<td>New fiber</td>
<td></td>
</tr>
<tr>
<td>Coating</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>b</td>
</tr>
</tbody>
</table>

Microbending Sensitivity (Relative Value)

Figure 1. Micro bending sensitivity of each fiber

In this time, we have selected the fibers, Type A, B, C, and D, with different macro bending characteristics each other. Then, we have manufactured a cable with these fibers.

2.2 The design of WTC with SWR

The structure of SWR with stripe ring marking is shown as Figure 2, stripe ring marking as Figure 3. SWR has single fiber part and bonding parts and adjacent fibers are fixed together intermittently, thus is possible to flexibly change its shape like bundle fiber units. Also, SWR can be spliced by a mass fusion splicer as well as a conventional rigid ribbon, and divided to individual fibers easily by using a simple tool or by hand.

The strip ring marking are printed in a line with ribbon width direction for easier identification of each ribbon and fiber after ribbon split.

Figure 2. Schematic of SWR

Figure 3. Schematic of Strip Ring Marking

The structure of WTC is shown in Figure 4. This cable consists of densely packed SWRs which are wrapped in a tube made by overlapping water blocking tape. Side strength members and rip cords are embedded in the sheath. Therefore, WTC achieved extremely reduced outer diameter and weight and full dry structure, to enhance workability during installation.

Figure 4. Structure of WTC

3. Characteristics of Trial Cable

We have manufactured a 144-fiber WTC applying above optical fibers, Type A~D. The temperature cycling and bending characteristics of the WTC shows in Figure 5 and 6.

Figure 5. Attenuation loss of 144-fiber WTC using each fiber

Figure 6. Bending characteristic of 144-fiber WTC

The results show that type D has good attenuation characteristic, which is almost same as Type B.
4. **Cable Performance of 1728-fiber WTC**

We have manufactured 1728-fiber WTC with SWR using the above fiber D, which has twelve units which consist of 144-fiber (12-fiber SWR times twelve) per unit. Figure 7 shows cross-section of the 1728-fiber WTC. We have evaluated this cable performance following as Telcordia GR-20.

![Cross-section of 1728-fiber WTC](image)

**Table 3. Mechanical test results**

<table>
<thead>
<tr>
<th>Item</th>
<th>Condition</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-high temperature cable bend</td>
<td>Bending radius:30D</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>Turns:3, Cycle:3</td>
<td></td>
</tr>
<tr>
<td>Impact</td>
<td>Striking surface:12.5mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Impct energy:4.4J</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Striking count:twice at the</td>
<td></td>
</tr>
<tr>
<td></td>
<td>same place</td>
<td></td>
</tr>
<tr>
<td>Compressive strength</td>
<td>200N/cm 10minutes after</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>220N/cm 1minute</td>
<td></td>
</tr>
<tr>
<td>Tensile strength</td>
<td>Load:2700N</td>
<td>Pass</td>
</tr>
<tr>
<td>Cable twist</td>
<td>Sample length:1m</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Test angle:+90deg</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cycle:10</td>
<td></td>
</tr>
<tr>
<td>Repeated bending</td>
<td>Bending radius:10D</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>Cycle:25</td>
<td></td>
</tr>
</tbody>
</table>

4.2 **Transmission characteristics under temperature cycling**

The attenuation change during the temperature cycling test was measured. Figure 8 shows the result of temperature cycling test between -40 °C and +70 °C for 2 cycles, and additionally, -50 °C is applied. Within this specified temperature range, maximum attenuation increase is less than 0.05dB/km at 1550nm. The developed cable exhibited good temperature cycling characteristics.

![Temperature cycling test result of the new WTC](image)

4.3 **Splice loss performance of 12-fiber SWR using the new fiber**

Figure 9 shows the histogram of splice losses at 1310nm. The averages of splice losses between the new fiber and Type A are about 0.025 dB.

![Splice loss between the new fiber SWR and Type A SWR](image)

5. **Conclusions**

We have developed the WTC with SWR using the new fiber based on ITU-T G652 D with improved the macro bending and the micro bending characteristic.

Applying new combination of fiber and its coating resin, excellent cable mechanical and environmental performance were obtained. By using the new fiber, we have also developed the ultra high density 1728-fiber WTC.

By this innovative cable, we can expect further expansion of applicable ranges of SWR&WTC.

6. **References**


using 200µm coated fiber", Proceeding of 63rd IWCS, 2014 p

7. Pictures of Authors

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