Design of Ultra-High-Density Optical Fiber Cable With Rollable 4-Fiber Ribbons

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This paper describes a new design for an Ultra-High-Density optical fiber cable with a rollable 4-fiber ribbon. The new cable has a sheath configuration similar to that of the conventional non-slotted optical cable and contains a rollable ribbon consisting of fiber adhesive parts and single-fiber parts alternately arranged in longitudinal and transverse directions. Unlike the conventional ribbon that generally maintains its shape with fibers lying on a straight line, this new ribbon freely changes its shape, providing the highest fiber density with reduced attenuation and residual strain in the cable. Thus, this ribbon reduces the diameter of the optical fiber cable. Furthermore, this ribbon provides handling characteristics equivalent to conventional ribbons and offers forward compatibility.

Keywords: rollable ribbon, bundle material, ultra-high-density, compatibility

1. Introduction

The number of FTTH subscribers in Japan has already reached 22 million in 2012 and it will increase slightly over the next several years. **Figure 1** shows a typical FTTH wiring configuration in Japan. To construct an FTTH network more economically, it is necessary to make effective use of existing ducts and spaces for the installation of optical fiber cables. In order to meet such demands, several studies for ultra-high-density optical fiber cable(1) have been conducted by Y. Yamada et al. and one of them will be the first to come into practical use.

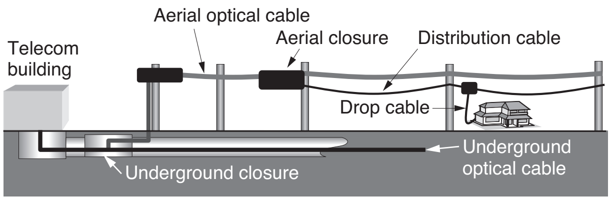

Fig. 1. Common wiring system in Japan

2. Rollable Ribbon

2-1 Design of the rollable ribbon

As shown in **Fig. 2**, the rollable ribbon consists of fiber adhesive parts and single-fiber parts alternately arranged in longitudinal and transverse directions. Fiber adhesive part X and single-fiber part Y are easy to change. To change the new ribbon to the closest packed structure at any cross-section in a longitudinal direction, any cross-section must consist of only 2-fiber adhesive parts and single-fiber parts should never include fixed 3-fiber adhesive parts. The optimum single-fiber part ratio (Y/X) should be determined from the viewpoint of fusion splicing workability.

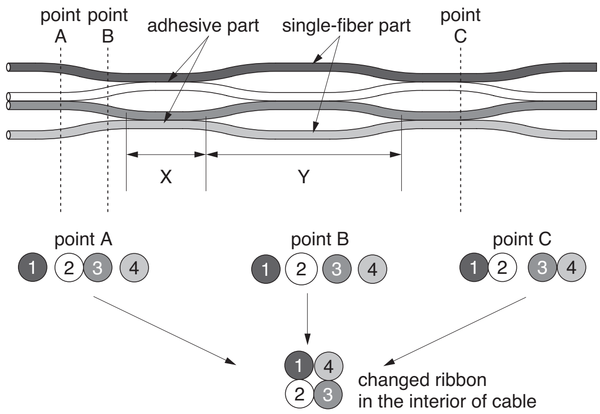

Fig. 2. Configurations of rollable ribbon

As one example, we have conducted a fusion splicing workability test using prototype ribbons with various combination of X and Y. As shown in **Table 1**, the larger single-fiber part ratio increases the operation time, which is due to the optional procedure of putting single fibers on folders for the multi-fiber fusion splicer.

On the other hand, when the Y/X ratio is close to 1, it is possible that the fixed 3-fiber ribbon part appears at any

Table 1. Fusion splice workability

sample	proportion Y/X	operation time (relative value)
sample 1	1.0	1.0
sample 2	1.5	1.1
sample 3	2.0	1.2
sample 4	4.0	1.4

cross section due to process deviation. We have optimized the Y/X ratio 1.5 (sample 2) to meet both splice workability and ribbon productivity.

2-2 Characteristics of the developed ribbon

Table 2 summarizes the optical and mechanical properties of the rollable 4-fiber ribbon and its compatibility with optical accessories. We confirmed that the ribbon has excellent properties and is compatible with conventional SC and MT connectors.

Table 2. The test results of the rollable 4-fiber ribbons

Item	Conditions	Results
Attenuation Coefficient	λ=1550nm	< 0.20dB/km
Temperature Cycling	-40 to 70˚C, 5cycles, λ=1550nm	Δ α < 0.05dB/km
Crush	490N/100mm, λ=1550nm	No loss change
Tensile Strength	IEC60793-1-31	> 43.2N
Strippability of ribbon resin	Hot remover	Success rate of 100%
Compatibility of connecter	Workability test	(Field Assembly) SC connecter Good
		MT connecter Good

2-3 Fusion splice loss

Fusion splice loss between the rollable 4-fiber ribbons, as well as between the developed ribbon and conventional ribbon were measured. The results are shown in **Fig. 3**. We confirmed that the splice loss of these ribbons is sufficiently low.

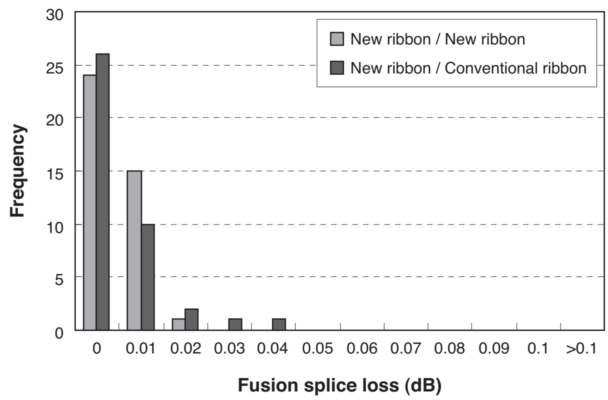

Fig. 3. Loss distribution at multi-fiber fusion splice

3. Ultra-High-Density Optical Fiber Cable

3-1 Unit identification

The Ultra-High-Density cables using rollable 4-fiber ribbons are often distributed in dimly lit and narrow spaces, and therefore, easy identification of the optical fiber units is required. The colored threads used for conventional units are thin and difficult to identify. In addition, as the diameter of the colored threads is similar to that of an optical fiber, workers can mistake the optical fiber as the thread. Therefore, easy identification of the units was investigated using a new material, such as colored wide tape as shown in **Fig. 4**. As shown in **Table 3**, when using the colored wide tape, the operation time required for unit identification is 60% shorter than using colored threads.

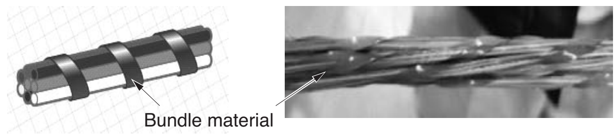

Fig. 4. Picture of the units bundled colored wide tapes

Table 3. Unit identification comparison

Bundle material	Bundle number	Unit identification	
		Time (Relative value)	Workability
Colored thread (conventional)	2 (Cross)	1.0	Better
Colored thread (Twice as many fiber volume)	2 (Cross)	0.8	Better
2.0mm colored tape	1	0.4	Excellent
2.5mm colored tape	1	0.3	Excellent

3-2 Characteristics of the aerial cables

As a representative example, the configuration of a 200-fiber cable is shown in **Fig. 5**.

Using the rollable 4-fiber ribbons and non-slotted configuration, we could reduce the cable size and weight drastically. Additionally, the structural components, such as the 20-fiber bundle unit and wrapping tape, are designed to

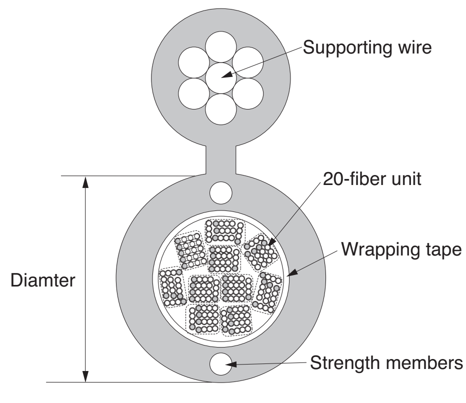

Fig. 5. Cross-section of 200-fiber aerial cable

help easily identify.

We have produced 24 to 200 fiber-count downsized cables, which were applied with bend-insensitive single-mode fibers that comply with the ITU-T G.657.A1 standard.

The cable diameter and weight is shown in **Table 4**, and the fiber density of those cables are shown in **Fig. 6**. The cables were downsized in diameter by 20-30% and in weight by 20-50%. The fiber density of the 200 fiber-count cable compared with a conventional cable was doubled.

We also evaluated the transmission and mechanical properties of the developed cables to conduct temperature cycling and mechanical tests.

Table 4. Relative values of cable diameter and weight

Fiber count		Conventional	ultra-high-density cable
24	Diameter	1	0.8
	Weight	1	0.8
100	Diameter	1	0.8
	Weight	1	0.5
200	Diameter	1	0.7
	Weight	1	0.5

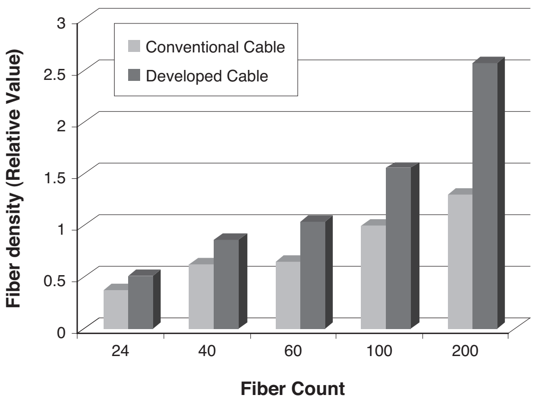

Fig. 6. Comparison of fiber density of the developed cables (relative values)

The test items, conditions, and results are summarized in **Table 5**. It was confirmed that attenuation changes of these cables were low in temperature cycling and mechanical tests.

3-3 Characteristics of the Water-blocking type cables

We have also developed 100 and 200 fiber count Water-blocking type cables with rollable 4-fiber ribbons. As shown in **Fig. 7**, the configuration is similar to that of the aerial non self-supported cable, but the wrapping tape used is the water blocking type. We conducted water penetration tests using the cables. As shown in **Table 6**, we confirmed that the cables have sufficient water-blocking property.

Table 5. Transmission and mechanical performance (Example in 200-fiber count cable)

Item	Method	Result
Attenuation coefficient	IEC60793-1-40 λ=1550nm	< 0.25dB/km
Temperature cycling	IEC60794-1-2 -30 ~ +70, 3cycles λ=1550nm	< 0.10dB/km
Crush	IEC60794-1-2 1960N/100mm λ=1550nm	< 0.05dB
Impact	IEC60794-1-2 1kg, 1m, λ=1550nm	< 0.05dB
Repeated bending	IEC60794-1-2 Bending radius:160mm 10cycles, λ=1550nm	< 0.05dB
Torsion	IEC60794-1-2 +/-90degree/1m 1cycles, λ=1550nm	< 0.05dB
Bending under tension	1960N, R=250mm λ=1550nm	< 0.05dB

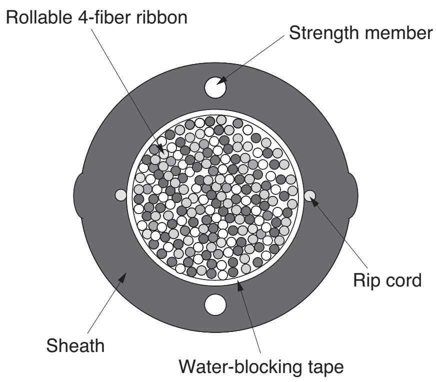

Fig. 7. Cross-section of 200-fiber WB cable

Table 6. Water blocking performance

Item	Method	Result
Water penetration	Height of water =1m Sample length=40m Artificial sea water	No water leakage at unsealed end

4. Conclusion

We have developed a rollable 4-fiber ribbon and Ultra-High-Density optical fiber cable. The workability of the ribbon is compatible with conventional ribbons. The cables were decreased in diameter 20-30% and in weight 20-50%. It was also confirmed that this cable has excellent transmission and mechanical properties.

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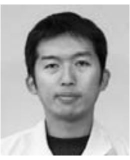

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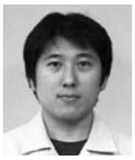

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