Development of 40/100-Fiber Cables for Underground Distribution

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As of December 2011, the number of FTTH subscribers in Japan has reached 21 million and is forecast to increase at a consistent pace. To construct FTTH networks more economically, a distribution system using underground conduits has been proposed. In this system, distribution cables are installed in underground conduits and drop cables are routed to each subscriber's home upon request for FTTH service at the midpoint of distribution cables. Here we have developed 40-fiber and 100-fiber cables as distribution cables which have good workability characteristics even in a dimly-lit and narrow space.

Keywords: underground distribution cable, FTTH, 40/100-fiber

1. Introduction

In Japan, the total number of broadband contracts has exceeded 37 million subscriptions at the end of December 2011. The FTTH (Fiber To The Home) service using an optical fiber has reached 21,890,000 subscriptions which occupied about 60% of the whole [(1)].

The composition of cable networks is also diversified by the expansion of the FTTH service. To construct FTTH networks more economically, a distribution system using underground conduits has been proposed. In this system, distribution cables are installed in underground conduits and drop cables are routed to each subscriber's home upon request for the FTTH service at the midpoint of distribution cables.

Underground cables are required different performances such as accessibility at dimly-lit space and waterproof performance. This paper reviews the 40/100-fiber cables that we have developed to meet these demands.

2. Network Configuration and Characteristics

Figure 1 shows a typical FTTH network configuration in Japan. Drop cables branch off to each house from the aerial cables which are connected to underground trunk cables.

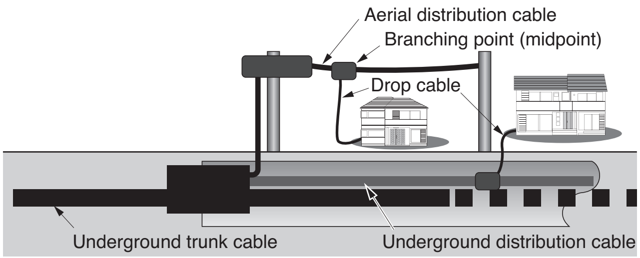


Fig. 1. Typical FTTH network configuration

For the network area, after taking the order for subscription, a closure is installed on the midpoint of the aerial cable, and a drop cable is branched from the aerial cable and installed to the costumer's house. In the closure, optical fibers are treated barely, and therefore, we developed new aerial cables which consist of ø0.5mm optical fibers in 2005. Because of the thickness of the optical fiber, the cable shows excellent connecting workability. **Figure 2** shows the cross section of the ø0.5mm optical fiber aerial cable.

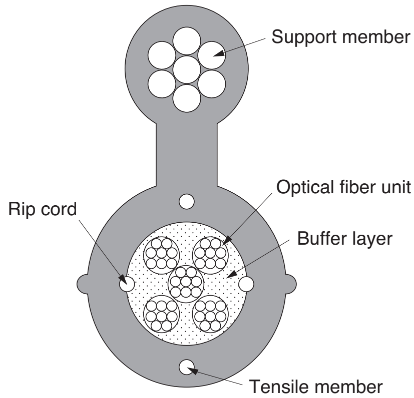


Fig. 2. ø0.5mm optical fiber aerial cable

The ø0.5mm optical fiber aerial cable is a non-slotted core cable and its optical fiber units, each of which consists of fibers bundled with color-coded thread, are wrapped by buffer material. The jacket contains the tensile members and rip cords.

In these days, to improve the city landscape, new configurations in which drop cables are pulled up from underground cables have been considered (**Fig.1**). In view of this, we have designed new underground cables, taking account of the following characteristics.

- Applying ø0.5mm optical fibers
  As in the case of the aerial cable, we applied ø0.5mm optical fibers to improve connecting workability at midpoints.
- Easy identification of optical fiber units
  As the distribution work of underground cables is often conducted in dimly-lit, narrow space, easy identification of optical fiber units is required.
- Waterproof performance
  Waterproof performance is required to prevent water ingress into the cable.
- Adaptation to underground closures
  The jacketing needs to be designed to maintain the airtightness of underground closures.

3. Cable Design

This section describes the design of a 40-fiber non-slotted core cable developed for underground distribution.

3-1 Optical fiber cable structure

Figure 3 and Table 1 show the structure and specifications of 40-fiber non-slotted core cable, respectively. As in the case of the aerial cable, five optical fiber units each of which consists of eight fibers are arranged in the center of the cable. The five units are wrapped with a water swellable tape and then covered with a jacket containing tensile members and rip cords.

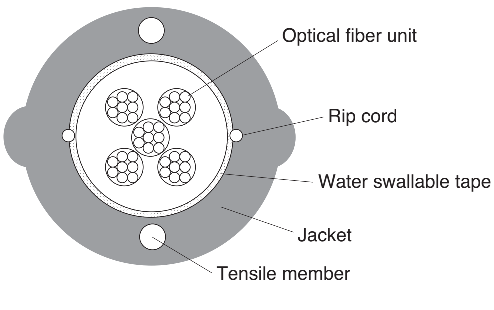


Fig. 3. Cross section of 40-fiber non-slotted core cable

Table 1. Specifications of 40-fiber non-slotted core cable

Term	Content
Fiber	ø0.5mm fiber (R15)
Unit	5-bundles of 8-fibers
Bundle material	Colored tape
Water blocking material	Water swellable tape
Jacket material	Polyethylene
Outer diameter	10.5mm

3-2 Selection of bundle material

As mentioned above, underground cables are often distributed in dimly-lit and narrow space, and therefore, easy identification of optical fiber units is required. The colored thread used for aerial cables is thin and difficult to see. In addition, as the diameter of the colored thread 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 tape as shown in **Fig. 4**.

As shown in **Table 2**, when using the colored tape, time required for unit identification is 60% shorter than that using a colored thread.

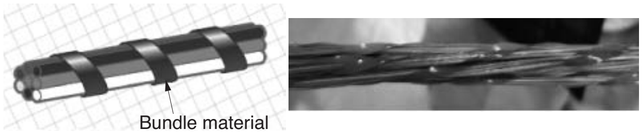


Fig. 4. Colored bundle tape

Table 2. Unit identification comparison

Bundle material	Number of thread/tape	Unit identification	
		Time (Relative value)	Workability
Colored thread (conventional)	2 (Cross)	1.0	△
Colored thread (Twice fiber volume)	2 (Cross)	0.8	△
2.0mm colored tape	1	0.4	○
2.5mm colored tape	1	0.3	○

Here, the 2.5mm colored tape can be recognized more easily than the 2.0mm tape, but the difference is small. As an increase in the volume of colored tape becomes an obstacle to the downsizing of the cable diameter, we selected a 2.0mm tape this time.

3-3 Selection of water blocking material

Unlike conventional non-slotted core cables used as aerial cables, the newly developed cables need to have a waterproof property for underground installation. For this purpose, we tested two types of water blocking material as follows.

(a) Yarn: Polypropylene yarn containing water swellable powder (**Fig. 5**, left).
(b) Tape: Wrapping tape coated with water swellable powder. Cable cores are wrapped with the tape (**Fig. 5**, right).

Both materials are commonly used for slotted core cables, and we confirmed that both of them have waterproof properties sufficient for underground installation. There-

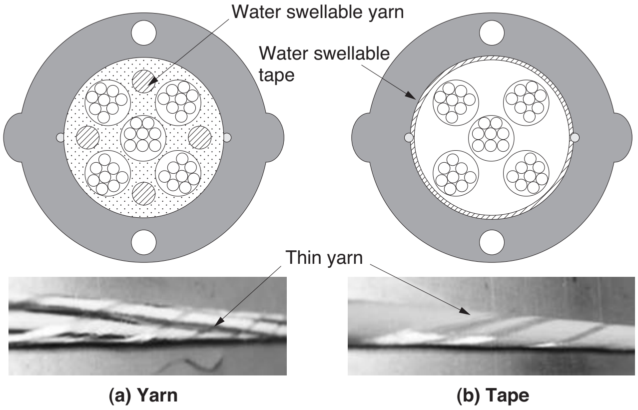


Fig. 5. Water blocking material composition and cable cores

fore, we selected water blocking material based on the ease of removal of optical fiber units from the cable core.

The procedure for the removal of a unit from the cable core is as follows.

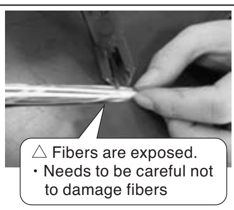
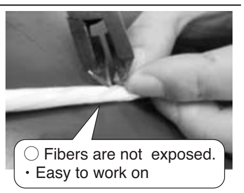
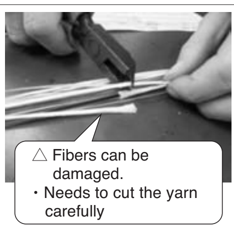
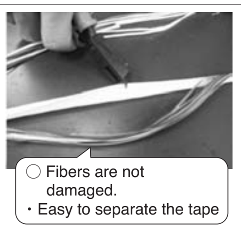
i) Remove the jacket and expose the cable core.
ii) Remove the bindings wound on the outer surface of the cable core.
iii) Remove the water blocking material that inhibits the fiber connecting operation.
iv) Pick up an optical fiber unit and take out a fiber for splicing.

In order to evaluate the procedure, we performed an identification test and measured the working time. **Table 3** shows the unit identification procedure and **Fig. 5** shows the working time, respectively.

In the case that water swellable yarn is used, optical fibers are exposed as the yarn does not cover them completely. The yarn has to be cut carefully not to damage the fibers. Moreover, when cutting several strands of water swellable yarns, the operator needs to be careful not to mix up the fiber with the yarn.

On the other hand, as the water swellable tape covers the optical fiber completely, the operator can cut the bindings safely and easily as shown in **Fig. 6**. Time required for removing the tape is 30% shorter than that for removing the yarn due to the difference in unit identification. Therefore, we selected water swellable tape as a water blocking material.

Table 3. Unit identification

Operation	Yarn	Tape
ii) Removing bindings		
iii) Removing water blocking material		

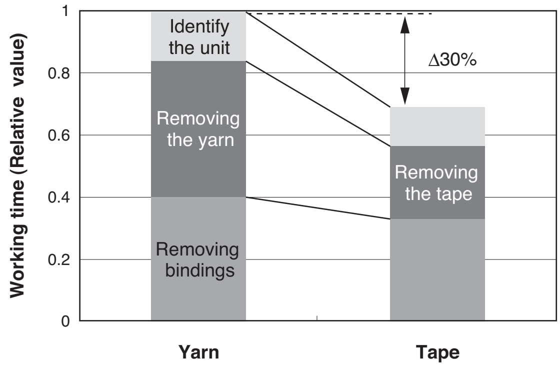


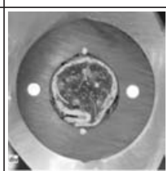
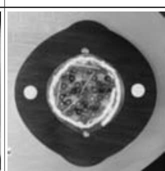
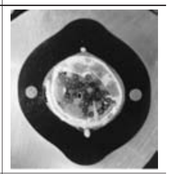
Fig. 6. Comparison of working time

3-4 Shapes of ledges

There are two ledges on the jacket as a work guide of the rip cord to makes it easy to pick up the rip cord and remove the jacket. In addition to a good visibility of the ledges, the airtightness of the closure is also important for installation.

Therefore, we performed an airtightness test using a commercial underground closure. We tested three ledge forms as shown in **Table 4**. As a result, it was found out that the shape of a ledge as well as the size affect the airtightness of the closure. This time, we applied middle-size ledges, considering cable handling.

Table 4. Relations between ledge form and airtightness

	Small size	Middle size	Large size
Cross section			
Ledge form (Height: relative value)	・Same as aerial cable ・Height: 1	・Gentle form ・Height: 2	・Gentle form ・Height: 3
Airtightness	Fail	Pass	Pass

* Test conditions: Initial pressure 39.2 kPa. Over 31.6 kPa after -20 ~ +60°C × 100 cycle.

3-5 Cable performance

We performed a temperature cycling test and mechanical tests for the newly developed cable. The test items, conditions and results are summarized in **Table 5**.

Table 5. Transmission and mechanical performance

Item	Method	Result
Attenuation	Wavelength 1550nm	＜0.25dB/km
Temperature cycling	-30~70°C × 3 cycles Wavelength 1550nm	＜Δ0.15dB/km
Tensile	900N	Loss fluctuation ＜0.1dB No damage
Bend	R160mm × 10 cycles	
Crush	1960N/100mm	
Impact	1kg × 1m	
Torsion	±90degree/1m 10 cycles	
Squeeze	900N, R=300mm	
Distortion	BOTDR	＜0.05%
Water penetration	Artificial seawater Height of water: 1m L: 40m	Pass
Airtightness	-20~+60°C 100 cycles	Pass (≧31.6kPa)

The results show that this cable has good transmission, mechanical and environmental characteristics for the underground application.

4. Development of Related Products

We developed a 40-fiber non-slotted core cable and 40/100 fiber slotted core cables simultaneously. Slotted core cables have higher mechanical performances compared to non-slotted core cables because optical fibers are protected by a slot. The slotted core cables can be used in a frozen duct and other severe environments.

4-1 Cable structure

Figure 7 shows the structure of the newly developed 40/100 fiber SZ slotted core cables. Cable characteristics are shown in **Table 6**. As in the case of a non-slotted core cable, five optical fiber units, each of which consists of eight fibers, are arranged in the cable. In the case of the 40-fiber cable, one unit is inserted per each slot, whereas in the case of the 100-fiber cable, three units can be inserted (only the last unit is a 4-fiber unit). The slotted core is wrapped with the water swellable tape and jacketed.

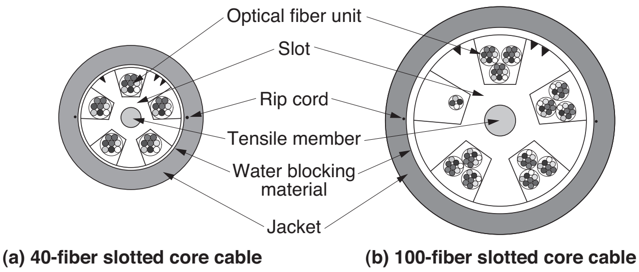


Fig. 7. Cross section of slotted core cables

Table 6. Specifications of SZ-slotted core cables

Item	Content	
	40 fibers	100 fibers
Fiber	ø0.5mm fiber (R15)	
Unit	Bundle of 8 fibers × 5	Bundle of 8 fibers × 12 Bundle of 4 fibers × 1
Bundle material	Colored tape	
Slot material	High density polyethylene	
Jacket material	Polyethylene	

SZ slots are applied for various installations. The SZ-slotted core cables can serve for extra length compared to helical slotted cables, and therefore, operations to identify the fibers are improved.

4-2 Comparison of crush resistibility

Slotted core cables have higher mechanical performances than compared to non-slotted core cables to be applied in ay the tough environment conditions like a frozen duct. We tested the crush resistibility of the non-slotted core cable and slotted core cables. **Figure 8** shows the deformation of these cables in a crash examination. The deformation of the slotted core cables is smaller than that of the non-slotted core cable. We confirmed that the slotted core cable can withstand twice the crashing force of a non-slotted cable. Although we will not go into details, slotted cables have good transmission, mechanical and environmental characteristics.

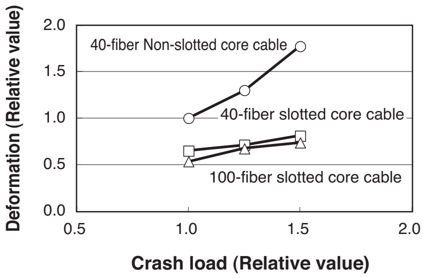


Fig. 8. Deformation in the crash examination

5. Conclusion

We have developed a 40-fiber (ø0.5mm) non-slotted core cable and 40/100-fiber (ø0.5mm) slotted core cables for underground distribution. We applied a colored tape as the bundle material and a water swellable tape as the water blocking material to improve unit identification. These newly developed cables have good transmission, mechanical and environmental characteristics.

References

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