3000-Fiber Optical Cable using 200 μm Fiber

Yusuke TSUJIMOTO,[1] Noriaki YAMASHITA,[1]
Akira NAMAZUE,[1] and Ken OSATO[1]

The demand of optical fibers has been expanding as the capacity of communication network has been increasing. In Japan, there is a strong demand for small-diameter and high-density optical cables to increase the number of fibers in a conduit in order to achieve both installation cost reduction and larger capacity. This paper introduces the high density 3000-fiber cable utilized for underground network, which has been achieved by using 200 μm fibers and furthermore by applying Spider Web Ribbon™ / Wrapping Tube Cable™ (SWR™ / WTC™).

1. Introduction

Recently the demand of optical fibers has been greatly increasing as the expansion of cloud services, 5G commercialization, the automated car driving systems and so on. To fill this demand, if existing underground conduits for laying cables can effectively be utilized, they should contribute greatly to cost reduction. In Japan, conduits of 29 mm inner pipe diameter are widely used. Thus to lay a cable in an inner pipe smoothly, the maximum outer diameter of the cable must be 24 mm or less. Although the transmission capacity has been increasing, it still needs to improve the number of fibers in a limited space. Under this current situation, the development of smaller diameter and higher density of the optical cables is indispensable and highly expected. Figure 1 shows the installation technology of multiple optical cables. In Japan the maximum count of fibers per cable is 2000 by using 250 μm fibers and it is possible to increase the number of fibers up to 6000 per conduit [1]. On the other hand, in other areas such as North America and Europe, 200 μm fiber are broadly spread. In order to increase the fiber count in a limited space of the cable, we have examined the 200 μm fiber and develop a new high density optical cable. We optimized the intermittently fixed ribbon structure, designed the maximum number of fibers in a cable of outer diameter of 24 mm and proved its characteristics. This paper introduces the achievement of this new cable that has successfully realized higher density than 2000-fiber optical cable and can be stored in just the same size of inner pipe.

2. Cable design

2.1 Consideration of 8-fiber structures

8-fiber ribbon is used for high fiber count cable. Figure 2 shows the comparison of the structures of three types of 8-fiber ribbon. The conventional rigid ribbon (Type A) is fixed in the width direction and it has been used in a slotted core cable. But in recent years, intermittently fixed ribbon has been introduced to obtain a high density cable. Accordingly we considered the structures of 2-fiber ×4 ribbon (Type B) and 1-fiber ×8 ribbon (Type C). 2-fiber ×4 ribbon (Type B) consists of 2-fiber rigid ribbons. On the other hand, 1-fiber ×8 ribbon (SWR, Type C) has a structure in which each fiber is intermittently bonded and it can

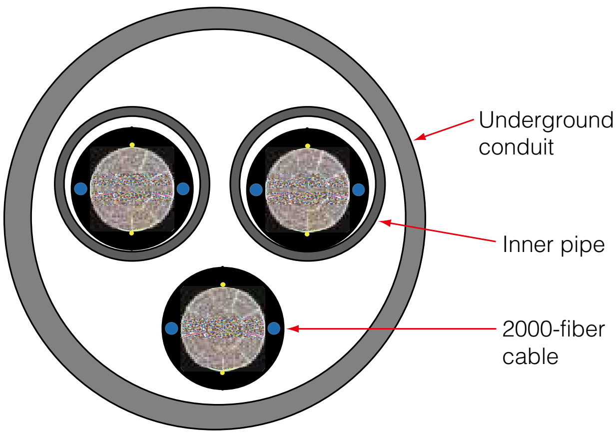

Fig. 1. Installation technology of multiple cables in an underground conduit.

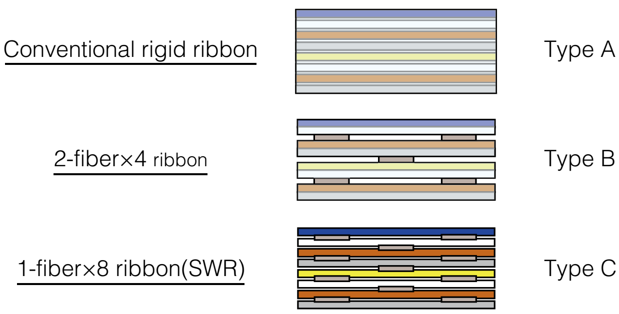

Fig. 2. Three types of 8-fiber ribbon.

1 Optical Cable Research and Development Department Optical Cable Systems Division

be transformed easily in a cable as shown in figure 3[2].

Figure 4 shows the maximum fiber strain by Brillouin Optical Time Domain Reflectometry (BOTDR) when two ribbons (Type B, Type C) are inserted in the same cable. Type C has approximately 40% lower fiber strain than Type B. And the structure of Type C get less fiber strain with a same packing density in a cable.

Figure 5 shows the relation between fiber attenuation and fiber packing density when two types of ribbon (Type B, Type C) are inserted in a cable at the different packing density relatively. Type B shows large fiber attenuation increases as the packing density increases. On the other hand, Type C shows good characteristics at the same packing density in a cable as Type B. Fiber packing density is defined in the following formula[3].

$D = F / S$

where,

- D: fiber packing density (fibers / mm^2)
- F: total fiber count in a cable (fibers)
- S: cross section of a cable – inclusion other than fiber (mm^2)

From above the researches, we conclude Type C is the most suitable structure for high packing density cable and a smaller diameter.

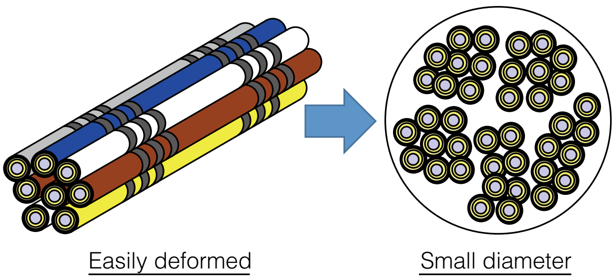

Fig. 3. Fiber packing in a cable.

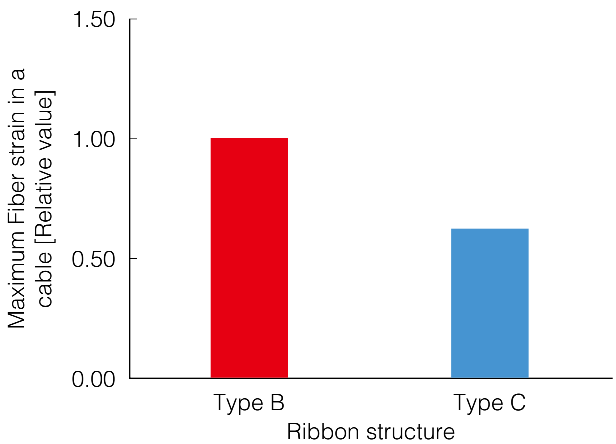

Fig. 4. Comparison of fiber strain between two structures.

2.2 Concept of SWR

The 250 µm fiber is commonly used for optical fiber network in japan. When using 200 µm fiber, it is necessary to consider the mass fusion splicing with 250 µm fiber in order to apply to existing network. Thus we developed a unique structure of SWR using 200 µm fibers in the same pitch of 250 µm fibers as shown in Figure 6[4].

By this arrangement of 200 µm SWR, mass fusion splicing to the conventional rigid ribbon can be easily and collectively performed with general fusion splicers without special holders. The measurement result of fusion splicing loss of 200 µm SWR to 250 µm rigid ribbon is shown in Figure 7, which indicates good fusion splicing loss. Figure 8 shows the fusion splicing time. There is no difference between two types of fiber ribbon structures. From these results, 200 µm SWR has excellent splicebility.

2.3 Design of high fiber count cable

In order to install a cable in the inner pipe (ϕ29 mm), the outer diameter of the cable must be less than

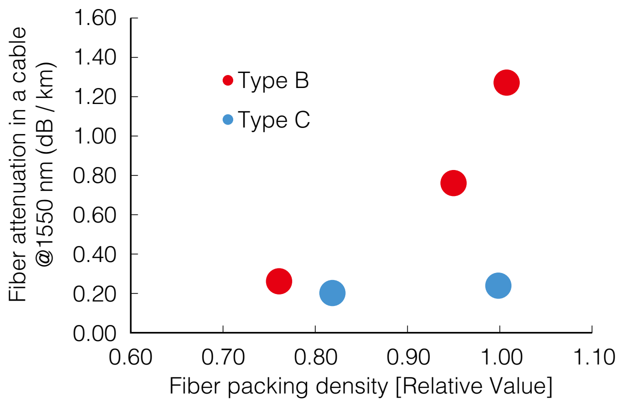

Fig. 5. Relation between fiber attenuation and fiber packing density of two structures.

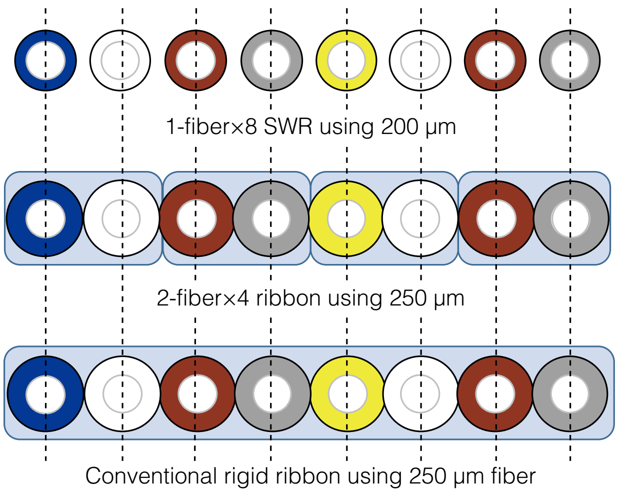

Fig. 6. Design of SWR using 200 µm fibers.

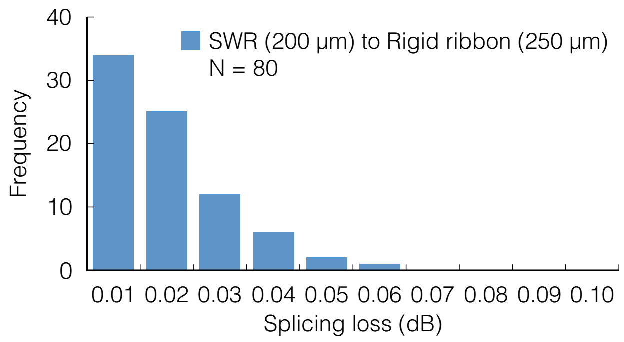

Fig. 7. The fusion splicing loss.

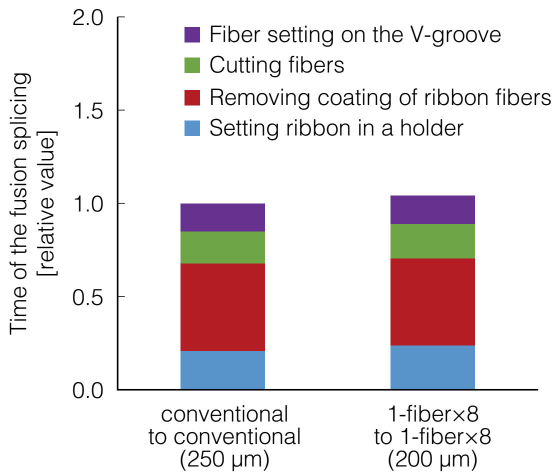

Fig. 8. The fusion splicing time.

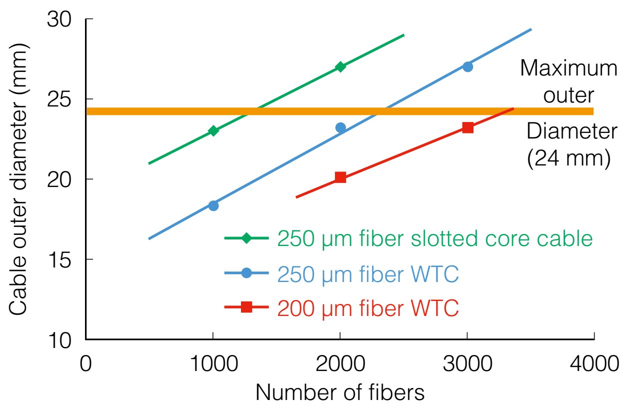

Fig. 9. Design of high fiber count cable.

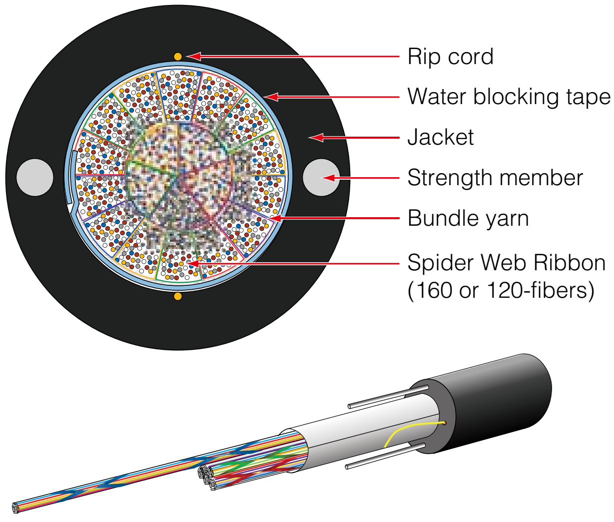

Fig. 10. Cable construction of 3000-fiber WTC.

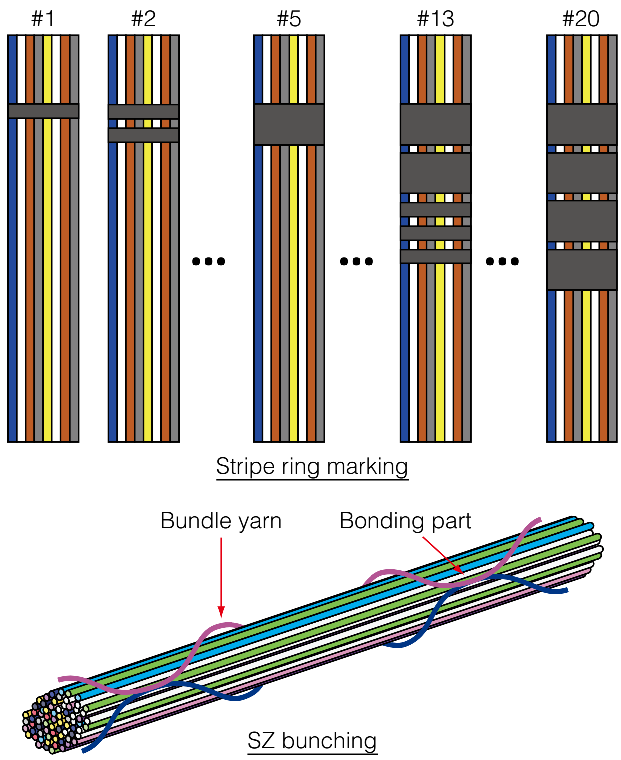

Fig. 11. Schematic of stripe ring marking and structure of SZ bunching.

24 mm. To estimate the maximum number of fibers that can be packed in a cable, we designed a high density WTC in which 200 μm fiber SWR are adopt. Figure 9 shows the relation between cable diameter and the number of fibers in a cable. In the case of slotted core cable using conventional rigid ribbon and WTC using 250 μm fiber SWR, the maximum number of fibers are 1000 and 2000 respectably. On the other hand, 200 μm fiber SWR can achieve a maximum number of 3000-fiber cable and make the cable smaller than others.

2.4 Cable structure

Figure 10 shows a construction of newly designed 3000-fiber WTC. 18 units of 160 fibers and 1 unit of 120 fibers are formed, therefore totally 3000-fibers are packed. The fiber core is wrapped around by a water blocking tape and covered with a jacket in which a pair of strength members are embedded. This structure is called Wrapping Tube Cable (WTC).

In order to identify fibers easily and correctly, SWR has a stripe ring mark on it and fiber unit has a SZ bunching structure as shown in Figure 11. Since the

Table 1. Characteristics of 3000-fiber WTC.

Item	Condition	Result
Attenuation	IEC 60793-1-40	< 0.35 dB / km@1310 nm < 0.25 dB / km@1550 nm
Water penetration	Height of water: 1 m Artificial seawater 40 m, 240 h	< 40 m
Repeated bending	IEC 60794-1-21 R240 mm × 10 cycle	< 0.05 dB No damage
Crush	IEC 60794-1-21 Crush 1960 N / 100 mm × 1 min.	< 0.05 dB No damage
Torsion	IEC 60794-1-21 ±90 ° / m × 10 cycle	< 0.05 dB No damage
Impact	IEC 60794-1-21 10 J	< 0.05 dB No damage
Temperature cycling	IEC 60794-1-22 −30 ˚C+70 ˚C, 3 cycle	Δ< 0.05 dB/km@1550 nm

Table 2. Line up of WTC.

250 μm -fiber	Fiber count	100	200	400	1000	2000	3000
	Cross section						-
	Diameter	10.0 mm	12.0 mm	14.0 mm	18.5 mm	23.0 mm	-
	Weight	80 kg / km	110 kg / km	150 kg / km	260 kg / km	400 kg / km	-
200 μm -fiber	Fiber count	100	200	400	1000	2000	3000
	Cross section						
	Diameter	8.8 mm	10.3 mm	14.0 mm	17.4 mm	21.4 mm	22.9 mm
	Weight	65 kg / km	80 kg / km	140 kg / km	230 kg / km	325 kg / km	370 kg / km

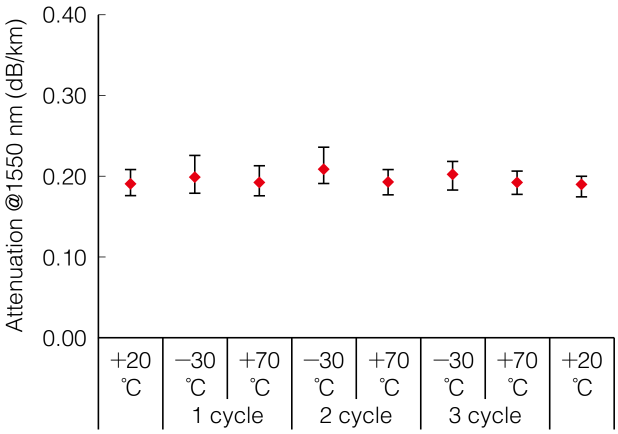

Fig. 12. Result of temperature cycling test.

stripe ring mark is printed on this SWR along the ribbon longitudinal direction, it can be easily identified even if 8-fiber SWR get separated to a single fiber. In addition, the SZ bunching wrapped around the fiber unit enables easy identification among fiber units. In case of a slotted core cable, whole ribbons from multiple slots are not bundled each other and that makes difficult to pick up targeted fibers among the bunch of fibers [5].

3. Cable performance

Table 1 shows the mechanical and environmental characteristics of 3000-fiber WTC. The test methods were based on IEC 60794-1-2. The wavelength for the tests was 1550 nm. Figure 12 shows the results of the temperature cycling test under the temperature of −30 / +70°C, 3cycle. 3000-fiber WTC obtained excellent mechanical and environmental characteristics.

4. Comparison with existing cable

The cables from 100 to 3000-fiber using 200 μm fiber and 250 μm fiber respectively are designed. Table 2 shows the WTC lineup. 200 μm SWR / WTC technology makes it possible to achieve significantly smaller diameter and higher density.

5. Conclusion

3000-fiber WTC using 200 μm fiber with an outer diameter of 24 mm was developed. The new cable has the same diameter as the conventional 2000-fiber WTC using 250 μm fiber. SWR / WTC technology magnificently reduces both the outer diameter and the weight of the cable compared to the existing cable. As a result, the new cable enables the maximum fiber count to grow in number up to 9000 in a conduit. This innovative cable will contribute to the economical and effective construction of optical fiber network.

References

1) N. Ito et al., "Development of 2000-fiber ultra-high density underground cable," Proceedings of 64th IWCS, pp.664-668, 2015.
2) M. Yamanaka et al., "Ultra-high density optical fiber cable with spider web ribbon," Proceedings of 61st IWCS, pp.37-41, 2012.
3) M. Ohno et al., "Development of ultra-high density and fiber-count WTC with SWR," Proceedings of 66th IWCS, pp.312-316, 2017.
4) D. Takeda et al., "Development of wrapping tube cable with SPIDERWEB RIBBON using 200 μm coated fiber," Proceedings of 63rd IWCS, pp.757-762, 2014.
5) M. Isaji et al., "Ultra-high density wrapping tube optical fiber cable with 12-fiber spider web ribbon," Proceedings of 62nd IWCS, pp.605-609, 2013.