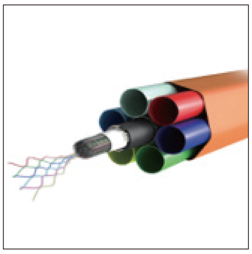
SUMITOMO ELECTRIC TECHNICAL REVIEW



Ultra-High-Density Microduct Optic Cable with Freeform Ribbons for Air-Blown Installation

Yohei SUZUKI*, Toyoaki KIMURA, Fumiaki SATO, Ken TAKAHASHI, Yuji NORISUGI, and Takao HIRAMA

This paper describes newly designed ultra-high-density (UHD) microduct optic cables that are installed into microducts using air-blown technique in order to efficiently build optical transmission capacity in data centers and other facilities. Our microduct cables range from 96-fiber to 864-fiber cables, including 288-fiber cable with flame retardant properties. The UHD microduct cables employ Freeform Ribbon, in which fibers meet and split out repetitively in longitudinal and transverse directions, allowing high fiber density and efficient fusion splicing. In order to enhance the cable-blowing performance, we choose a thin and lightweight cable design with low friction jacket material. These microduct fiber optic cables can be used in various environments, contributing to the efficient and flexible network designs suited to data centers and other customer needs.

Keywords: 12-fiber Freeform Ribbon, high-fiber-count, air blowing, microduct, outdoor/indoor

1. Introduction

In Europe and North America, microduct optical cables are in widespread use in building optical cable networks. Once a duct (microduct) is installed, the cable can later be installed without extra road works, making it possible to construct networks economically. Meanwhile, in recent years, communication traffic has increased rapidly due to progress in cloud computing, video streaming services, and support for 5G. There has been a growing need to increase the fiber count and density of microduct optical cables due to physical constraints in the internal spaces of ducts. Because a cable is pushed into a duct by feeding high-pressure compressed air (air-blowing method, see Figs. 1 and 2) for installation, it must be thin and lightweight, its jacket must have low friction, and adequate rigidity must be ensured to prevent the cable from kinking when pushed into a duct. We have developed Freeform Ribbon microduct optical cables (from 96-fiber to 864-fiber) for the above-mentioned air-blowing method, that reduce the connection cost than the conventional single-fiber optical cables. This paper also reports the development of outdoor/indoor microduct optical cables, which can be used in both outdoor and indoor environments, and employ a flame-retardant jacket to reduce the construction cost by eliminating connection points from outdoors into a building.

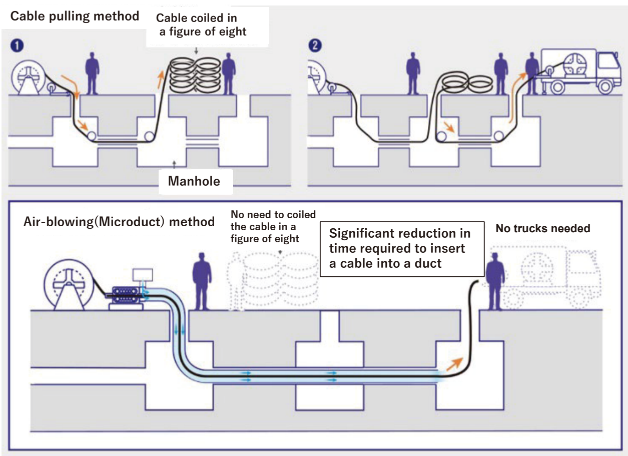


Fig. 1. Comparison between the cable pulling method and the air-blowing method

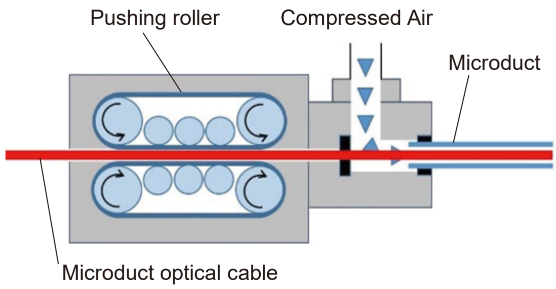


Fig. 2. Schematic diagram of the cable blower

2. Structure

2-1 Design of a Freeform Ribbon

The newly developed optical cables employ a Freeform Ribbon, shown in Fig. 3 (a) and (b).(1) This ribbon contains 12 fibers that is mainly used in the world. It has splits in the longitudinal direction for every two fibers to ensure both flexibility and ease of mass fusion splicing. These characteristics are controlled by optimizing the ratio and length of the split section and the non-split section. As shown in Fig. 4, a bar-shaped marking is provided on the surface of a ribbon, making it possible to identify a ribbon from multiple ribbons in a cable. We have developed optical cables using 200 µm and 250 µm fibers to meet various needs, including ease of identification in mass fusion splicing, customers' preferences in terms of handling, and compliance with international standards and end-user specifications.

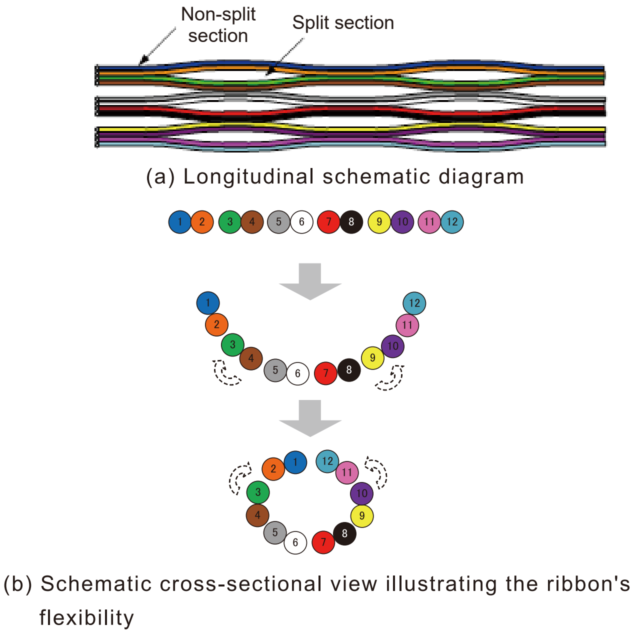


Fig. 3. Schematic diagram of 200 µm 12-fiber Freeform Ribbon

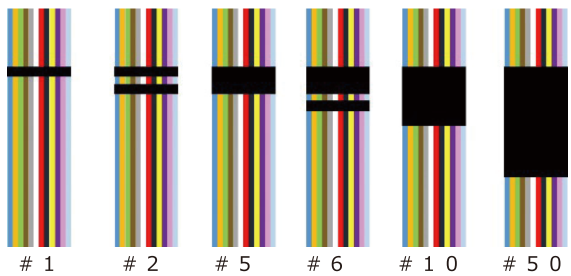


Fig. 4. Fiber Ribbon identification marking

2-2 Structure of optical cables

In this newly developed cable, a monotube structure (Fig. 5) is used to prioritize meeting the thin-diameter and light-weight requirements for air-blowing performance.[2] The thin strength members*[1] arranged in the jacket provide adequate rigidity for cable installation in the duct and reduce installation resistance that occurs in the bending direction. Regarding the jacket material, a low-friction material are used to improve the air-blowing performance. The friction coefficient of the low-friction jacket material is about one-fourth of that of a conventional general-purpose jacket material. For Outdoor/Indoor cables, a flame-retardant jacket material is used to impart flame-retardant performance, which is required of cables for installation in buildings. In general, the percentage of the amorphous region is high in flame-retardant jacket material and a decrease in the elasticity coefficient results in lower cable rigidity. Thus, we adopted a jacket material whose elasticity coefficient is more than double that of a conventional general-purpose flame-retardant jacket material.

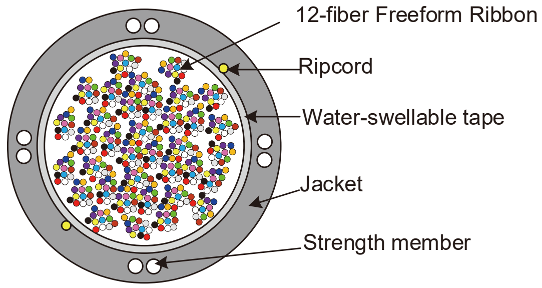


Fig. 5. Schematic cross section of a microduct optical cable (example)

To confirm the influence of the cable structure on air-blowing performance, the air-blowing installation was performed using cables whose outer diameter was between 9.5 mm and 10.5 mm to compare the air-blowing distance. 432-fiber optical cables packaging 200 µm fibers were used for the experiment. Three types of cable structures with different outer diameters, jacket materials, and rigidity levels were prepared (Table 1).

Table 1. Cable structures for evaluating air-blowing performance

Cable	Cable Diameter (mm)	Dynamic CoF† of the jacket material	Cable Stiffness (Nm^2)
Cable A	9.5	0.1	0.7
Cable B	10.5	0.1	0.8
Cable C	10.5	0.2	0.5

† Coefficient of Friction

These three types of cables were used to perform air-blowing installation in an air-blowing test circuit (length: 500 m) shown in Fig. 6. Figure 7 shows the relation of air-blowing distance to cable pushing force as test results. The inside diameter of the microduct was 13 mm.

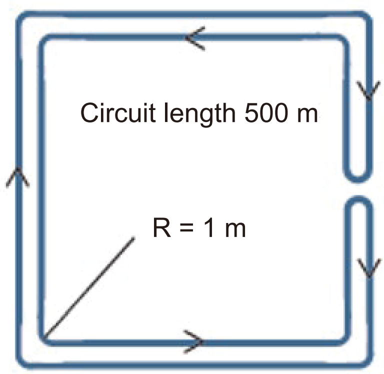


Fig. 6. Air-blowing test circuit

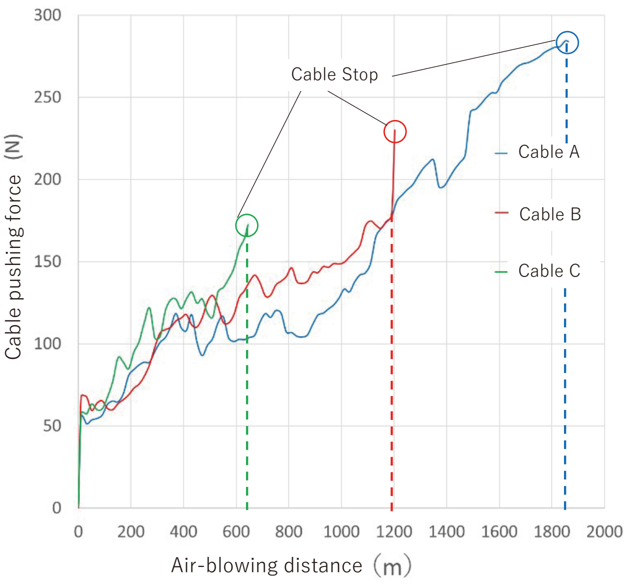


Fig. 7. Air-blowing test results

Cable A attained the longest air-blowing distance, followed by Cables B and C. Cable A, whose fill ratio was about 73%, achieved sufficient air-blowing capacity. Cables B and C, whose fill ratio was over 80%, were far inferior to Cable A in terms of the air-blowing distance. Adequate cable rigidity was required to push a cable into a microduct, and the dynamic friction coefficient of the jacket surface also had an influence. Accordingly, the air-blowing distance of Cable B was about double that of Cable C. Based on the above, the effective designs for microduct cable is a thin cable structure keeps the cable occupancy rate into microduct low, and to adopt a jacket material with the performance of both adequate rigidity and low friction. The same design was applied to all the newly developed cables (from 96-fiber to 864-fiber).

3. Cable Test Results

3-1 Transmission characteristics, mechanical characteristics, and air-blowing performance

Table 2 shows the evaluation results of the transmission characteristics, mechanical characteristics, and environmental characteristics of the newly developed optical cables (96-fiber to 864-fiber). The respective items were evaluated in accordance with the IEC standard. It was confirmed in all the tests that these cables have satisfactory characteristics.

The air-blowing test results are presented in Table 3. In a test circuit of 500 m (Fig. 6), it was confirmed that the air-blowing distances of 1.5 km or more, and 1 km or more were attained for outdoor cables and Outdoor/Indoor cables, respectively, at an air pressure of 14 MPa or less inside the duct, and a cable pushing force of 300 N or less.

3-2 Flame-retardant characteristics

Table 4 shows the results of the combustion and smoke tests on outdoor/indoor cables. It was confirmed that the cables met the combustion test standard of IEC 60332-3 Part 3 Category C (vertical-tray flame test), which applies around the world, and the high-flame-retardant characteristics of UL 1666 (riser cable flame test), which applies mainly in the U.S. Regarding EN 50399, which must be met in applications as construction materials in Europe, there would be got a prospect of fulfilling C_{ca} in the combustion test and ES2 in the smoke test.

Table 2. Characteristics evaluation results

Item	Test Method	Evalution Result
Attenuation Coefficient	IEC60793-1-40 λ = 1550 nm	< 0.30 dB/km
Temperature cycling	IEC60794-1-22-F1 -30~+70°C, 2 cyc. λ = 1550 nm	Loss variation < 0.3 dB/km
Compresive Loading	IEFC60794-1-21-E3 1000 N / 100 mm λ = 1550 nm	Loss variation < 0.15 dB No faulty condition in cable appearance
Impact Test	IEC60794-1-21-E4 2.5 N·m, 2 drop impacts λ = 1550 nm	
Cyclic Flexing	IEC60794-1-21-E6 Bending radius 20 D, 25 cycles ("D" denotes the outer diameter of the cable.) λ = 1550 nm	
Cable Twist Test	IEC60794-1-21-E7 ±180°, Tension 100 N λ=1550 nm	
Long Tensile Loading and Fiber Strain Test	EIA/TIA-455-33 Tension: 1334 N	≤ 60% of fiber proof level

Table 3. Air-blowing performance test results

Fiber Dia. 200 μm

Usage	Outside Plant					Outdoor/ Indoor
Fiber Count	96/144	192	288	432	864	288
Diameter	7.2 mm	8.2 mm	9.0 mm	9.5 mm	12.5 mm	10.5 mm
Duct Size	14/10 mm	14/10 mm	16/13 mm	16/13 mm	22/18 mm	16/13 mm
Air Blown Distance	≥1.5 km	≥1.5 km	≥1.5 km	≥1.5 km	≥1.5 km	≥1.0 km

Fiber Dia. 250 μm

Usage	Outside Plant					
Fiber Count	96	144	192	288	432	864
Diameter	7.6 mm	8.2 mm	8.7 mm	10.5 mm	12.0 mm	14.9 mm
Duct Size	14/10 mm	14/10 mm	16/13 mm	16/13 mm	22/18 mm	22/18 mm
Air Blown Distance	≥1.5 km	≥1.5 km	≥1.5 km	≥1.5 km	≥1.5 km	≥1.0 km

Table 4. Combustion/smoke test evaluation results

Item	Test Standard	Test Result
Combustion Test	IEC60332-3 Part3 Category C Flame propagation distance ≤ 2.5 m	Pass
	UL1666 Flame propagation distance < 366 cm	Pass
Smoke Test	IEC61034 Minimum light Transmittance ≤ 60%	Pass

4. Comparison of Work Time

We calculated the effect of reducing the installation time by using the outdoor/indoor cables. By imparting flame-retardant performance to the cables, it has become possible to install cables from the outdoors into a building without a connection point (Fig. 8). As shown in Fig. 9, the installation work time is expected to be reduced by about 33% for mass fusion splicing and by about 28% for installation work. There is a prospect of reducing work time by about 31% in total (compared to conventional products of Sumitomo Electric Industries, Ltd.).

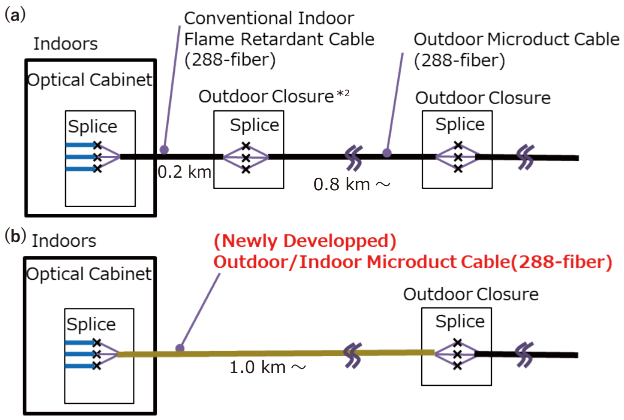


Fig. 8. Changes in the cable wiring style

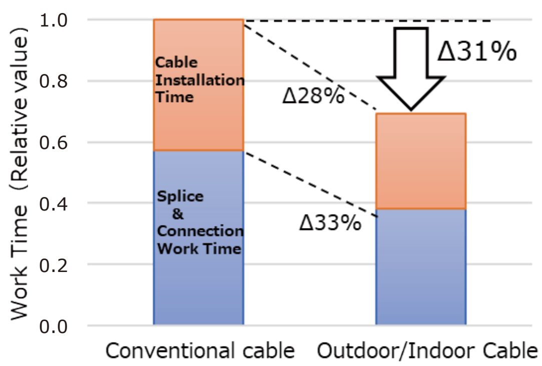


Fig. 9. Comparison of the work time

5. Conclusion

With the diversification of cable installation methods, the air-blowing installation has been performed on optical cables of various fiber counts, including low- and high-fiber-count cables. The cable structures have been optimized by improving air-blowing distance and high-fiber-count (up to 864-fiber) microduct cables have been newly developed. Outdoor/indoor microduct cables (flame-retardant microduct cables) have also been developed successfully to reduce construction work time by enabling direct installation into a building. Regarding flame-retardant microduct cables, 288-fiber cables are expected to reduce work time by 31% and come into frequent use to meet various needs. Although using a flame-retardant jacket increases the cable mass because its specific gravity is higher than that of a conventional non-flame-retardant jacket, an air-blowing distance of 1 km or more can be achieved. The combination with outdoor microduct cables makes it possible to build networks inexpensively and achieve flexible cabling configurations.

Technical Terms

*1 Strength member: This component relieves the tension applied to optical fibers during installation.

*2 Closure: This refers to a terminal box which is installed at connection and branch points of optical cables and in which optical fibers are connected. Closures are mainly used outdoors.

References

(1) F. Sato et al, "Characteristics of Ultra-High-Fiber-Count and High-Density Optical Cables with Pliable Ribbons," International Cable and Connectivity Symposium (2017), p.304

(2) F. Sato et al, "Ultra-Hig-Density Microduct Optic Cable with 200 μm Freeform Ribbons for Air-Blown Installation," SEI TECHNICAL REVIEW No. 89 (Oct 2019)

Contributors

The lead author is indicated by an asterisk (*).

Y. SUZUKI*
• Assistant General Manager, Optical Fiber & Cable Division

T. KIMURA
• Assistant General Manager, Optical Fiber & Cable Division

F. SATO
• Group Manager, Optical Fiber & Cable Division

K. TAKAHASHI
• General Manager, Optical Fiber & Cable Division

Y. NORISUGI
• Optical Fiber & Cable Division

T. HIRAMA
• Assistant General Manager, Optical Fiber & Cable Division