Development of Optical Fiber-Composite PVC Insulated Drop Wire

*by Fuminori Nakajima *, Soichiro Otosu *, Yoshiyuki Kamata *,*
*Takashi Kijima *2 and Jun'ichi Kawashima *3*

ABSTRACT In order to promote broad use of optical communications in common homes, installation of optical fiber cables to subscribers' premises should be much lower in cost, necessitating further studies on the wiring materials including optical fiber as well as on the installation method. Thus, it was considered that combining optical fiber with DV wire (PVC insulated drop wire) widely used for electric power distribution to private premises would be advantageous since the DV wire could serve as a tension member for optical fibers, thereby cutting the number of cable pieces to be installed. In an effort to develop an optical fiber drop cable, the authors investigated the structure of optical fiber unit suitable for combining with the DV wire, and subsequently evaluated their characteristics when they were integrated with the DV wire. As a result, optical fiber-composite PVC insulated drop wires with satisfactory performance have been developed. It is hoped that these cables promote the installation of optical fiber cables to subscribers' premises.

1. INTRODUCTION

Recently, with the increasing popularity of Internet in common homes as well as the demand for optical communications to enable distribution of moving pictures, implementation of FTTH (Fiber To The Home) is being studied by a variety of telecommunications service providers. In order to implement FTTH on a large scale, however, it is essential that the access network be constructed at an economical cost. As shown in Figure 1, conventional optical drop wire for subscribers' premises has been designed, assuming an independent installation of the optical fiber cable only, to have a steel suspension member to protect the optical fiber against the wire tension during and after installation. In electric power distribution, meanwhile, DV wire (PVC insulated low voltage drop wire) shown in Figure 2 is widely used for supplying electric power to private premises, so that integration of the DV wire with the optical fiber is considered to be advantageous in the following terms:

- The DV wire can be utilized as a tension-resistant member for the optical fiber, thereby simplifying the structure of optical drop cables.
- Installation of optical fiber on subscribers' premises is enabled without increasing the number of installed lines.
- The DV wire and the optical fiber can be installed simultaneously, so that installation costs can be minimized.

* Engineering Dept., Optcom Div.
*2 Engineering Dept., Electric Wire and Equipment Div.
*3 Distribution Dept., Chubu Electric Power Co. Inc.

The authors investigated, therefore, the structure of optical fiber cable that is suited for combination with the DV wire, and developed two types of optical fiber-composite PVC insulated drop wires (hereafter called OPDV): bundle type OPDV in which an optical fiber unit is stranded around the DV wire as well as tube type OPDV in which a tube is integrated with the DV wire allowing for post-insertion of optical fiber unit when need arises. A 2-fiber ribbon was used in these OPDVs assuming separation of up- and down-links. Figure 3 schematically illustrates the cable route configuration.

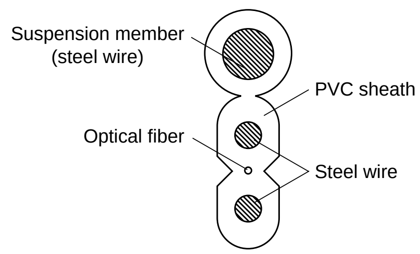

Figure 1 Conventional optical drop cable.

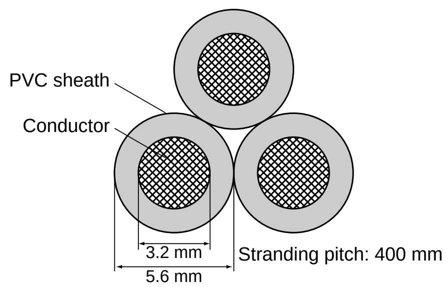

Figure 2 PVC insulated drop wire.

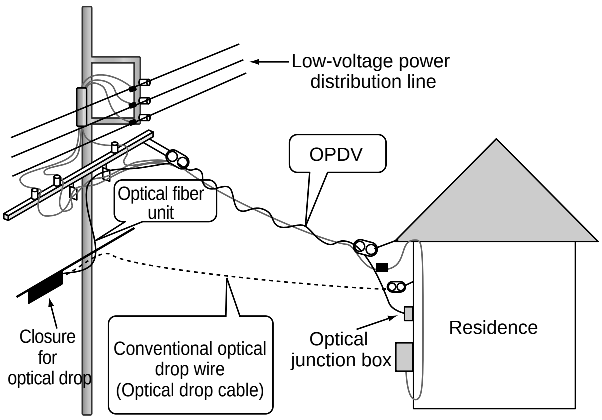

Figure 3 **Cable route configuration of OPDV.**

2. BUNDLE TYPE OPDV

2.1 Cable Structure

The basic structure of optical fiber unit for bundle type OPDV has been designed to be such that two tension members are disposed on both sides of a 2-fiber ribbon followed by PVC sheathing. The sheath is provided with two notches on the top and the bottom allowing for easy access to the fiber. To prevent the fiber from possible breakage due to electromagnetic repelling forces at the time of DV wire short-circuiting, the tension member employed non-metallic, glass FRP rod; and its diameter was decided to be 0.7 mm, taking into consideration its tensile properties and ease of stranding onto the DV wire. PVC was adopted as the sheathing material for its flame retardance equivalent to that of DV wire as well as because of its low cost. We carried out the following investigation in order to decide on the optimum cable geometry.

2.1.1 Investigation on the cable geometry

The OPDV is often squeezed, during its stringing work, through the supporting arm of electric poles as shown in Figure 4. We therefore fabricated prototypes of optical fiber unit having structures shown in Figure 5 (a) to (c), and evaluated each of them for their crush and squeeze resistance assuming stringing on the supporting arms.

Figure 6 shows the evaluation method of crush resistance using a square member. It was assumed that the optical fiber unit had different mechanical characteristics in the directions of parallel to and perpendicular to the two tension members as shown in Figure 7, so that the unit was tested by changing the direction of the load. Table 1 shows the test results. Furthermore, Figure 8 and Table 2 show the evaluation method and the results of the squeezing test, respectively.

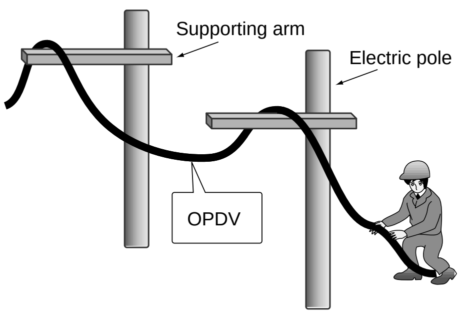

Figure 4 **Stringing of OPDV.**

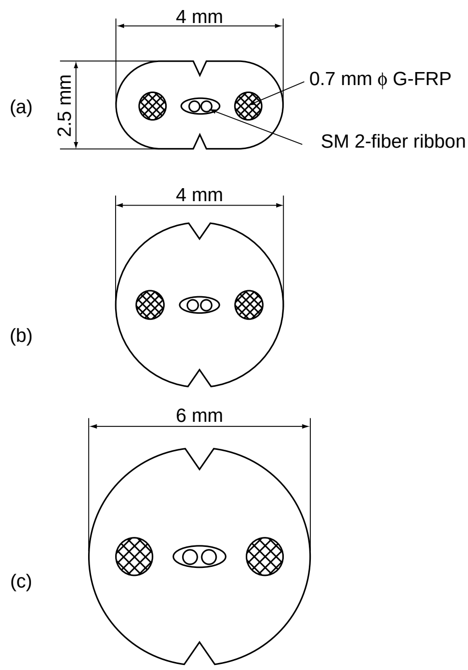

Figure 5 **Prototypes of optical fiber unit.**

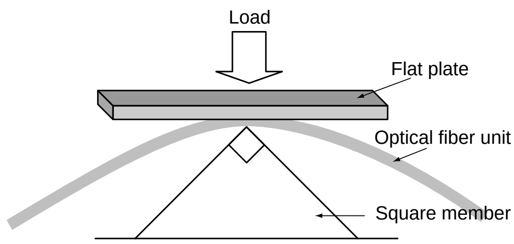

Figure 6 **Crush test using a square supporting arm.**

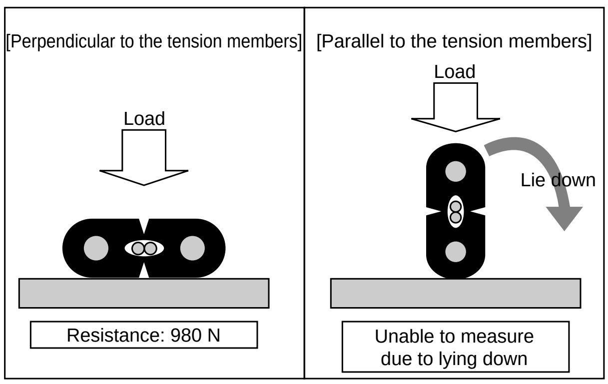

Figure 7 **Crush test configuration.**

From the results shown in Tables 1 and 2, it was concluded that the optimum geometry of the optical fiber unit is that shown in Figure 5 (a). Figure 9 shows the cross section of an OPDV which integrates this optical fiber unit with the DV wire.

3. TUBE TYPE OPDV

Tube type OPDV has been studied, in which a tube for optical fiber unit is integrated with the DV wire allowing for post-insertion of optical fiber unit when need arises. For its small friction, polyethylene was used as the material for the tube and the sheath of optical fiber unit, and the tube was sheathed with PVC to a thickness of 0.5 mm to provide flame retardance.

One of the key points in the development of tube type OPDV was how to assure an insertion length of optical fiber unit as far as 60 m, i.e., the maximum span of DV wires. Whereas air-blowing using compressed air has already been implemented for insertion of optical fiber units conventionally, this method needs dedicated equipment of large size and high cost such as compressors, making it difficult to be applied in space-limited working areas --e.g., on bucket vehicles and on electric poles. Consequently, we investigated various structures of tube type OPDV, bearing in mind the manual insertion of low cost and easy implementation.

Table 1 Results of the crush test using square supporting arm.

Optical fiber unit	Perpendicular to tension member	Parallel to tension member
Figure 5 (a)	980 N or less	Unable to measure due to unit lying down
Figure 5 (b)	780 N or less	390 N or less
Figure 5 (c)	1180 N or less	390 N or less

* Crush load with which no residual optical loss is detected at 1.55 ϕm is shown.

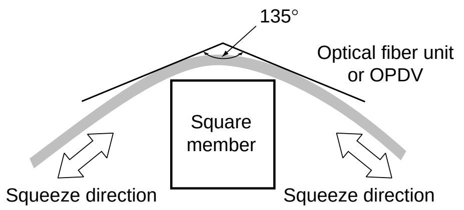

Figure 8 Squeezing test using a square supporting arm.

Table 2 Results of the squeezing test using square supporting arm.

Optical fiber unit	Squeezing test on optical fiber unit	Appearance of OPDV
Figure 5 (a)	No residual optical loss No external damage seen	No disorder
Figure 5 (b)	No residual optical loss No external damage seen	Disorder seen
Figure 5 (c)	No residual optical loss No external damage seen	Disorder seen

*Measured at 1.55 μm

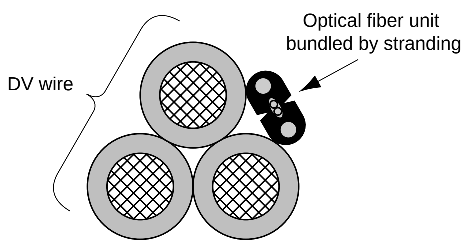

Figure 9 Cross section of bundle type OPDV.

3.1 Optical Fiber Unit for Manual Insertion

It was learned, according to the studies on insertion characteristics of optical fiber units into the tube, that the allowable insertion length of an optical fiber unit is correlated with its flexural rigidity. Figures 10 and 11 show the measurement method of the flexural rigidity and the relationship between the flexural rigidity and the insertion length of optical fiber units in straightened condition, respectively. A polyethylene tube with an inner diameter of 4.5 mm was used in the measurement. Based on these results, an optical fiber unit shown in Figure 12 was developed and achieved manual insertion of up to 60 m.

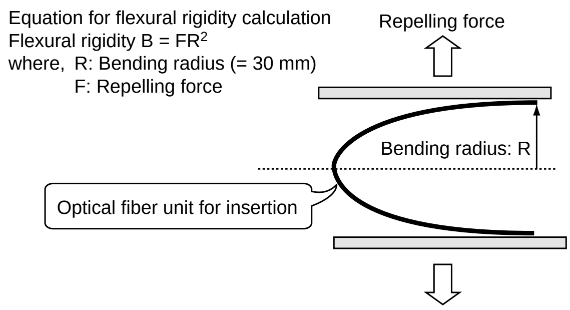

Figure 10 Measurement method of flexural rigidity.

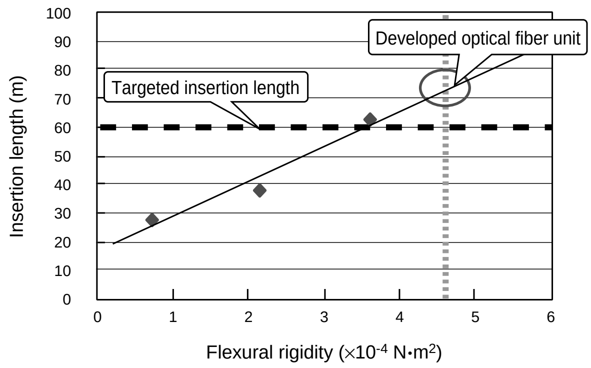

Figure 11 Relationship between the flexural rigidity and insertion length of optical fiber unit.

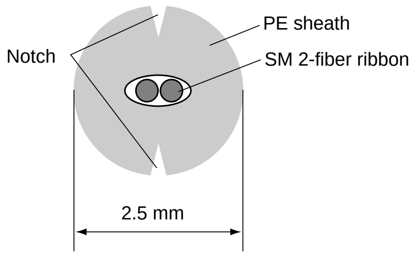

Figure 12 Optical fiber unit for insertion.

3.2 Investigation on Tube Integration

3.2.1 Tube stranding type

As a method to integrate the tube with the DV wire, stranding was studied first, and insertion lengths of the optical fiber unit were evaluated as described in Clause 3.1 by changing the stranding pitch. It was found, as shown in Table 3, that the stranding pitch of the tube should be 1 m or longer in this case where the DV wire itself was stranded with a pitch of 0.4 m. However, when a tube type OPDV with a stranding pitch of 1.4 m underwent an actual stringing work, disorder in the stranding pitch was generated and an insertion length of 60 m proved to be impossible, making clear that the cable was practically unusable. Moreover, such problems as collapsing of stranded tube surfaced when OPDVs with long stranding pitches were coiled, so that it was concluded that the tube stranding type was not suited for practical application.

Table 3 Relationship between stranding pitch and insertion length.

Stranding pitch of tube	Insertion length
0.6 m	35 m
1.0 m	60 m or more
1.2 m	60 m or more

*Stringing conditions: Span: 60 m; Sag: 1.2 m

3.2.2 Tube lashing type

In view of the conclusion that the tube stranding type was not suited for practical application, we employed a cable structure in which the tube was placed lengthwise the DV wire without stranding, and a lashing wire was used to bundle them. To prevent the fiber from possible breakage due to electromagnetic repelling forces caused by DV wire short-circuiting, aramid fiber was employed as the lashing wire material for its excellent tensile properties. Moreover, a PVC sheath 0.5 mm thick was applied on the aramid lashing wire, taking into account the weathering resistance, ease of handling and flame retardance upgrading of aramid fiber. Figure 13 shows the cross section of a tube lashing type OPDV.

4. CHARACTERISTICS OF OPDV

Characteristics of the two types of OPDV and the respective optical fiber units were evaluated. Table 4 shows the characteristics of the bundle type OPDV including its optical fiber unit for stranding, and Table 5 those of the tube type OPDV including its optical fiber unit for insertion. It has thus been confirmed that they have achieved excellent characteristics.

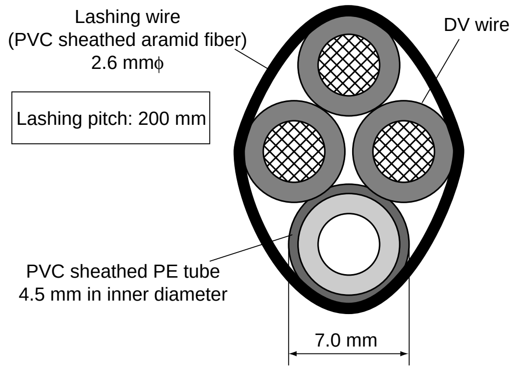

Figure 13 Cross section of tube type OPDV.

Table 4 Characteristics of bundle type OPDV and optical fiber unit for stranding.

Item	Bundle type OPDV		Optical fiber unit for stranding	
	Test conditions	Test results (@1.31 µm)	Test conditions	Test results (@1.31 µm)
Transmission characteristics Attenuation	—	—	—	0.34 dB/km
Temp. dependence	-20~60°C	0.01 dB/60 m or less	-20~60°C	0.01 dB/km or less
Mechanical characteristics Tension	2820 N	No residual loss, Elongation: 0.14 %	100 N	No residual loss
Bending	R70 mm, 180°, 5 times	No residual loss	R30 mm, 180°, 5 times	No residual loss
Compression	980 N/50 mm	No residual loss	1960 N/50 mm	No residual loss
Impact	0.5 kg/1 m, 10 spots	No residual loss	1 kg/1 m, 10 spots	No residual loss
Vibration	±5 mm, 10 Hz, 1 million times	No residual loss	±5 mm, 10 Hz, 1 million times	No residual loss
Twist	245 N, ±90°, 3 times	No residual loss	10 N, ±270°, 3 times	No residual loss
Flame retardance	JIS C 3005, inclined burning	Extinguished within 10 sec.	JIS C 3005, inclined burning	Extinguished within 10 sec.

Table 5 Characteristics of tube type OPDV and optical fiber unit for insertion.

Item	Tube type OPDV		Optical fiber unit for insertion	
	Test conditions	Test results (@1.31 μm)	Test conditions	Test results (@1.31 μm)
Transmission characteristics Attenuation	—	—	—	0.34 dB/km
Temp. dependence	-20~60°C	0.01 dB/60 m or less	-20~60°C	0.01 dB/km or less
Mechanical characteristics Tension	2820 N	No residual loss, Elongation: 0.17 %	5.7 N	No residual loss
Bending	R70 mm, 180°, 5 times	No residual loss	R30 mm, 180°, 5 times	No residual loss
Compression	980 N/50 mm	No residual loss	1760 N/50 mm	No residual loss
Impact	0.5 kg/1 m, 10 spots	No residual loss	0.5 kg/1 m, 10 spots	No residual loss
Vibration	±5 mm, 10 Hz, 1 million times	No residual loss	±5 mm, 10 Hz, 1 million times	No residual loss
Twist	245 N, ±90°, 3 times	No residual loss	—	—
Flame retardance	JIS C 3005, inclined burning	Extinguished within 10 sec.	—	—

5. SUMMARY

For accelerated implementation of FTTH, it is essential that optical fiber cable and its installation be low in cost. In this work, the authors have studied optical drop cables in order to reduce the cost of the cable as well as its installation, whereby prototype cables integrating optical fiber unit and DV wire were fabricated and were subsequently evaluated. As the result, two types of optical fiber-composite PVC insulated drop wire (OPDV) with excellent characteristics have been developed. It is hoped that the use of these OPDVs will promote broad installation of optical fibers to common homes.

Manuscript received on November 1, 2001.