# New Design of Optical Fiber Cable for Easy Mid-span Access

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*We have developed a new optical fiber cable for access network. The cable is designed to achieve the easier mid-span access as well as smaller diameter and light weight. In order to enhance these characteristics, the cable has the following features:*

- *Straight C-slotted rod*
- *Non-concentric sheath*
- *Design of strength member*
- *Dry structure*

*The cable is optimized with consideration of low temperature characteristics. For evaluation of the cable, the mid-span access time is compared with conventional access cables. We verified that the C-slotted core cable has good workability for mid-span access. In this paper, we describe the design concept and design parameters for minimizing the cable diameter. Moreover, we demonstrate not only that the trial cable has good mechanical characteristics and attenuation properties, but also that the mid-span access work is achieved about 2 minutes, which is 50 % shorter time than SZ-slotted core cables.*

## 1. Introduction

In recent years, access cables have seen a wide-spread use for the construction of fiber to the home (FTTH) networks in Japan. In order to construct these networks economically, the demands for improvement in cable installation are increasing. The mid-span access property, cable diameter and weight are important parameters for improving its workability. Easier mid-span access allows for short connection time with drop cables. Smaller diameter allows the efficient and flexible use of duct space. Light weight cable is suitable for long span installation[1) 2)].

## 2. Cable design

In order to achieve excellent workability for mid-span access, a new cable is designed. It consists of a longitudinal straight single C-slotted rod with strength member, two ripcords, water-blocking tape and non-concentric sheath with sub-strength member. This cable is designed on the basis of the following concepts:

1) C-slotted rod

The fibers are inserted in a C-slot as shown in Fig.1. This structure is similar to the conventional central tube structure, but the C-slot has an opening for picking out the fibers. This structure makes the mid span access operation easier than the conventional structures, such as loose tube cable, center tube type cable, SZ-slotted core cable. The fibers are fixed by the soft resin intermittently to prevent fiber movement.

2) Non-concentric sheath

The sheath is designed non-concentrically as shown in Fig.1. The C-slotted rod is weak at the opening, therefore the sheath of this point is designed thicker to compensate for the weakness of the C-slotted rod.

3) Design of strength member

The main strength member is located in the C-slotted rod, and the sub-strength member is inserted in the sheath as shown in Fig.1. The sub-strength member controls the cable bending direction in order to prevent the fiber strain. Moreover, this sub-strength

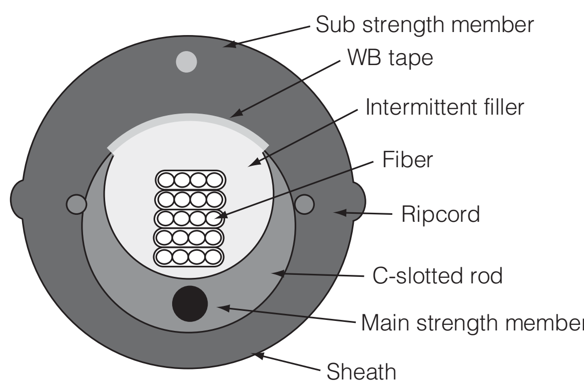


**Fig.1. Structure of newly developed cable.**

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member is made of FRP, which can be cut by a cutter easily.

4) Location of ripcords

In order to cut the sheath easily, the ripcords are located at both side of the C-slotted rod, and the location can be recognized by the small protrusion on the sheath surface as shown in Fig.1.

5) Dry structure

For easy fiber access, the opening of the C-slot is packed with water blocking tape linearly, without any binding yarn.

## 3. Temperature characteristics

### *3.1 Design parameter*

The cable is designed taking account of the fiber bending loss at low temperature. As the excess fiber length is larger and/or the space in a C-slot is smaller, the critical bending of the fiber occurs more easily at low temperature. Therefore, in order to achieve smaller cable keeping good temperature characteristics, the excess fiber length and the clearance in a C-slotted core cable must be designed carefully. Figure 2 shows the fiber-buckling model at low temperature.

Assuming the fiber bend is a sine curve, the relation between excess fiber length and fiber minimum bending curvature radius ρ is shown in following equation (1)[3]:

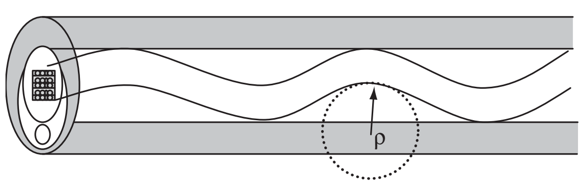



**Fig.2. Fiber buckling model.**

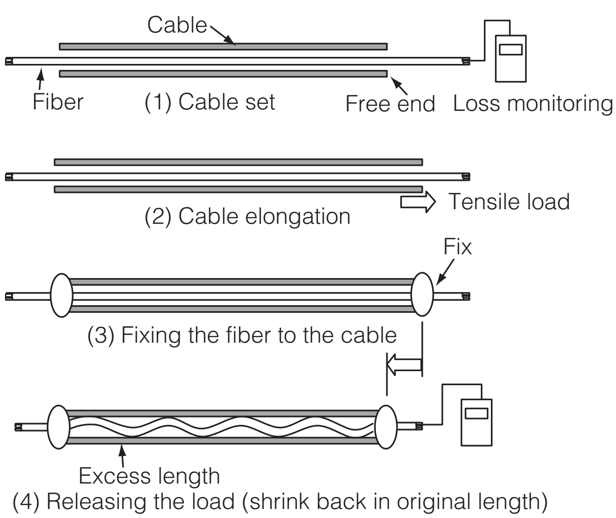



**Fig.3. Test procedures.**

$$\rho = \frac{a}{4\left(l - k\left(T_0 - T\right)\right)} \quad \cdots\cdots (1)$$

Here '$a$' is clearance in the C-slot. '$l$' is the excess fiber length ratio. '$k$' is the linear expansion coefficient of the cable. '$T$' is the cable temperature and '$T_0$' is the base cable temperature.

### *3.2 Fundamental experiment*

To minimize the cable diameter, it is important to determine the minimum allowable bending radius. In order to estimate the minimum curvature radius, a fundamental experiment was conducted. Figure 3 shows the procedures of the test. Several meters of C-slotted core cable with ten 4-fiber ribbons was used in this test. In this case, the fiber is not fixed to the cable so it can move freely (Fig.3 (1)). First, a constant tensile load is applied to the cable end. At that time, the fiber can slide into the cable relatively as much as cable elongation (Fig.3 (2)). Next, the fiber is fixed to the cable on the cable ends (Fig.3 (3)). After the tensile load is released; the excess fiber length is obtained relatively (Fig.3 (4)). According to the change of the tensile load, various excess lengths can be obtained. The loss is monitored during the test.

### *3.3 Results of fundamental experiment*

The measurement result is shown in Fig.4. The relation between attenuation and excess length was obtained.

Based on this result, the relation between attenuation and calculated bending radius ρ was obtained as shown in Fig.5. As ρ increases, the attenuation decreases gradually and above $\rho_{min}$, there will be no attenuation increase. $\rho_{min}$ refers to the minimum allowable curvature radius of the fiber in the C-slotted core cable.

In order to minimize the cable diameter, it is necessary to consider fiber clearance and the excess fiber length at low temperature. Figure 6 is parametric plot

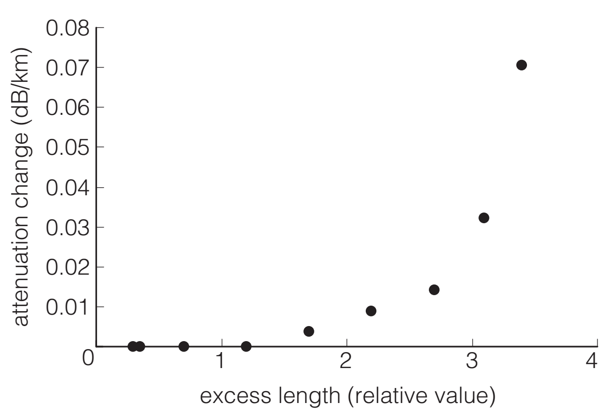



**Fig.4. Relation between attenuation change and excess fiber length.**

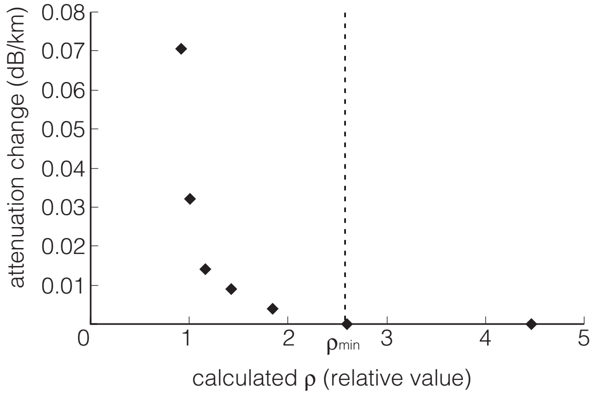



**Fig.5. Relation between attenuation change and calculated curvature radius.**

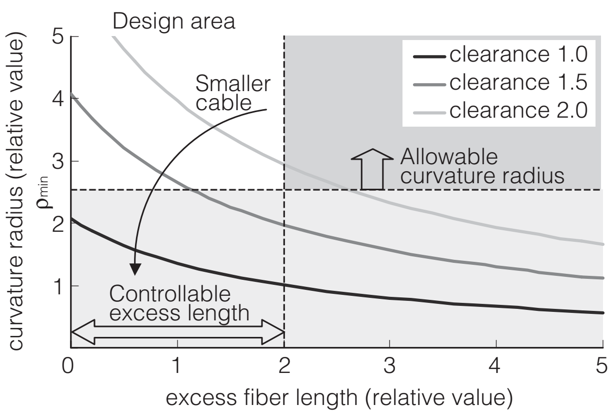



**Fig.6. Relation between attenuation change and calculated curvature radius at −30ºC.**

of equation (1). It shows the curvature radius versus excess fiber lengths at −30 °C, where clearance of 1.0, 1.5, 2.0 (relative value) is plotted as a parameter. By using the value of $\rho_{min}$ (obtained in Fig.5), the relation between clearance and excess fiber length at low temperature can be optimized. When the clearance is 1.0, there is no optimum excess fiber length because the curvature radius is less than $\rho_{min}$ (masked area in Fig.6). When the clearance is 1.5 or 2.0, good attenuation properties can be obtained by controlling the excess fiber length above $\rho_{min}$. However, because of the cable allowable elongation, the excess fiber length has a finite limit (shown in Fig.6). Hence C-slotted core cable is designed within this limited area.

## 4. Trial cable

With the above consideration, a 40-fiber cable composing of 4-fiber ribbons that uses conventional single mode fibers was manufactured. The cable diameter was 8.0 mm. To prevent the fiber movement, soft resin was put into a slot intermittently. The mechanical and environmental characteristics of the cable were examined.

**Table 1. Test result of trial cable.**

| Item | Test condition (Wavelength 1.55 µm) | Result |
|---|---|---|
| Transmission loss | 1.55 µm | < 0.22 dB / km |
| Crush | 2000 N / 100 mm | < 0.01 dB |
| Impact | 10 J | < 0.01 dB |
| Bending | R 160 mm | < 0.01 dB |
| Squeezing | 392 N R 250 mm | < 0.01 dB |
| Torsion | 1m, ±90 deg. | < 0.01 dB |
| Waterproof | 40 m 240 h | pass |

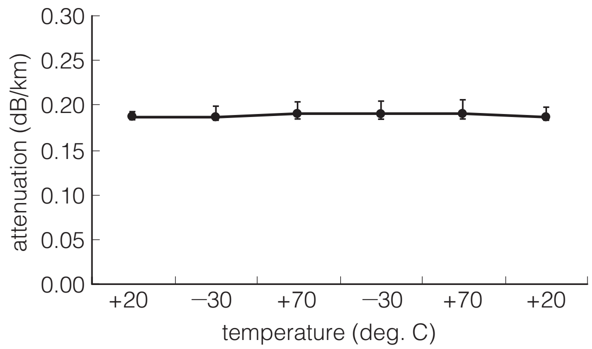



**Fig.7. Temperature cycling behavior of trial cable.**

*4.1 Mechanical characteristics*

The mechanical characteristics of the trial cable were examined according to the IEC 60794-1-2. The optical transmission loss after cabling and the mechanical test results are listed in Table 1.

*4.2 Optical characteristics*

The attenuation change during the temperature cycling test was measured. Figure 7 shows the result of temperature cycling test between −30 °C and +70 °C. Within this specified temperature range, maximum attenuation loss is less than 0.23 dB/km at 1.55 µm. The trial cable exhibited good attenuation properties in this test.

## 5. Mid-span access

The mid-span access can be easily performed according to following procedures (Fig.8):

1) Pulling out the ripcord: In order to pull out the ripcord, small cuts are made on both the sides of the cable sheath using a cutter. (Fig.8 a), b))
2) Removing the sheath: The two ripcords are pulled in each part to split the sheath apart. Each side of the sheath is then removed by using a cutter, revealing the C-slotted rod inside. (Fig.8 c), d))
3) Picking out target fiber: The C-slotted core has no binder and no wrapping, so the target fiber can be picked out easily. Additionally, due to excess fiber length, the fiber is loose within the slot, making mid-span access procedure easier. (Fig.8 e))

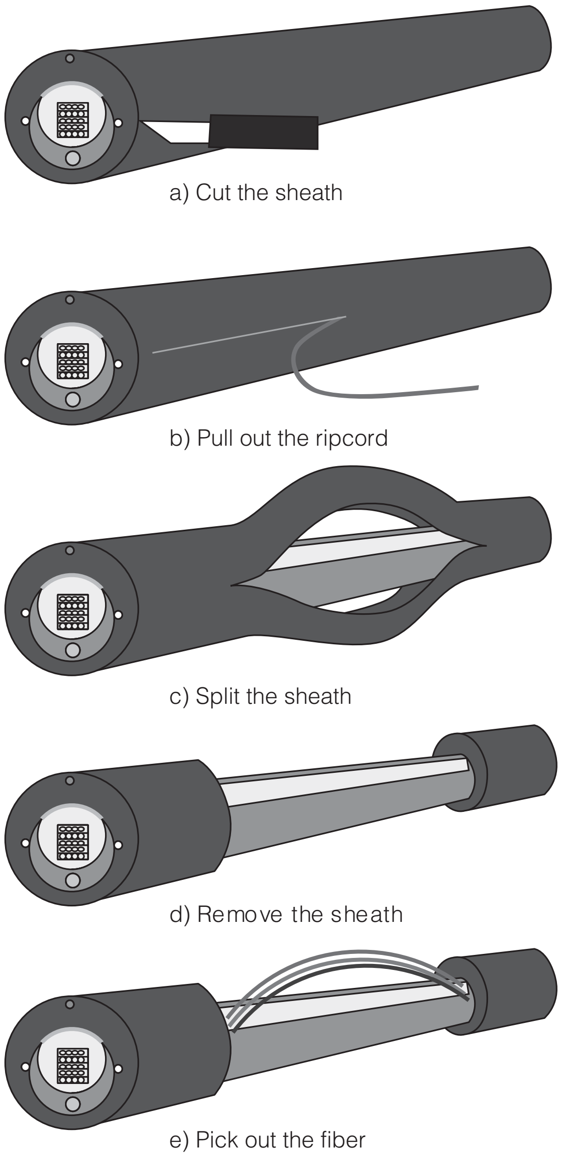
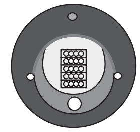
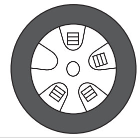



**Fig.8. Procedure of mid-span access.**

## 6. Comparison with conventional cable

To examine the mid-span accessibility, the mid-span access time is measured and compared with the conventional access cables, such as SZ-slotted core cable and central tube cable. The results are shown in Table 2. The mid-span access time of the C-slotted core cable is less than 2 minutes. The cable is smallest and lightest among these cables. This result demonstrates that the C-slotted core cable is very suitable for mid-span access.

**Table 2. Comparison of trial cable and SZ-slotted core cable.**

| Cable type | Structure | Diameter | Weight | Mid-span access time |
|---|---|---|---|---|
| C-slotted core cable |  | 8.0 mm | 0.05 kg/m | 2 min. |
| SZ-slotted core cable |  | 11.0 mm | 0.10 kg/m | 4 min. |

## 7. Conclusions

In this paper, we introduced the newly developed cable that enhances the cable mid-span access workability. The cable is constructed with a C-slotted rod and non-concentric sheath. The cable has a small diameter of 8.0 mm and light weight of approximately 0.05 kg/m. By optimizing the excess fiber length, we obtained good transmission performance in wide temperature range from −30 to +70 °C. The mid-span access procedure time is about 2 minutes, which is faster than conventional access cable. We verified that C-slotted core cable has good workability for mid-span access.

### References

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