Multi-fiber Hardened Optical Connector Suitable for 5G Optical Network Infrastructure

Daiki Takeda,[1] Naoyuki Ozawa,[1] Toshiaki Nakajima,[1] and Kansei Shindo[1]

In recent years, with the spread of network services such as 5G, simpler optical connection work is required. Generally, working skill and experience were required because optical connections in optical termination boxes or optical closures were made by fusion splicing or field installable connectors. Therefore, we have developed a multi-fiber hardened optical connector for outdoor use that is compact and has excellent connection workability. The developed product has a uniquely designed connector structure, which makes it compact, yet has robust mechanical characteristics, and is also excellent in waterproofness. The optical characteristics, mechanical characteristics, and waterproof characteristics of the prototype were evaluated and confirmed to be excellent.

1. Introduction

Recently as growing the various network services such as 5G, the demand for optical connection construction has increased. Figure. 1 shows an example of conventional optical cable wiring[1)]. The optical cables are generally induced into the optical closure which is located on the pole or in the handhole. The optical fibers in the optical cable are branched and connected to another optical fiber in the optical drop cable. The optical fibers are connectorized with each other, and the optical junction is made by the connectors, with the technology of Fusion-splicing technology[2)] or Mechanical splicing technology[3)].

However, the conventional optical connection method requires a certain amount of operator-dependent skills, such as the handling of optical closures and the splicing of optical fibers.

So it is desired that the optical junction will be constructed simpler and quicker.

We have developed the hardened optical connector which is able to connect 24 fibers at once, and this will make the connection action easier and quicker than conventional optical connection.

Some example applications are shown as below. First, the hardened optical connector can be used as an alternative where an optical closure is required as shown in Fig. 2 (a). Compared with applying an optical closure, it is be able achieve smaller connection points and quicker construction to apply the hardened connector.

Furthermore, the hardened connector can be equipped onto the optical closure as shown in Fig. 2 (b). By pre-implementing hardened connector, the optical wiring can be branched from the optical closure. The feature of this application is that optical connection can be easily constructed without opening/closing the optical closure or fusing the optical fibers.

In this paper, the details of the structure and characteristics of the developed hardened optical connector are introduced.

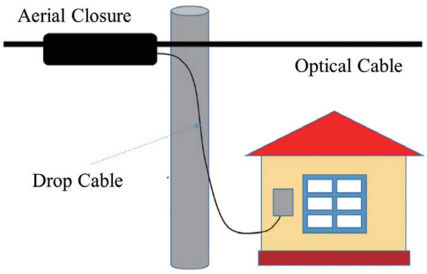

Fig. 1. Schematic of cable wiring.

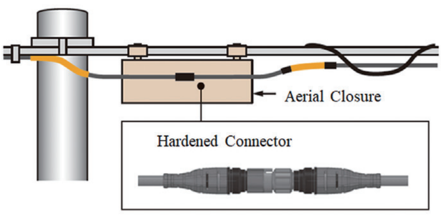

Fig. 2(a). Example deployment for replacement of the closures.

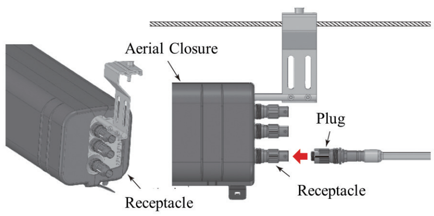

Fig. 2(b). Example deployment of hardened connector onto the closures.

1:Fiber Optics Network Product R&D Department

Abbreviations, Acronyms, and Terms.

FTTH—Fiber To The Home
A network configuration method for access optical communication in which optical fiber is directly connected to individual homes as a transmission line.

SWR—Spider Web Ribbon
Intermittently fixed fiber ribbon. Due to partially fixing multiple fibers in the longitudinal direction, this is an epoch-making fiber tape that combines the benefit of a single fiber with the convenience of a fiber ribbon.

WTC—Wrapping Tube Cable
An optical cable with a wrapping tube structure. Since the cable is made of only optical fiber, presser winding and sheath, the cable achieved the ultimate optical fiber cable structure with no waste.

MT ferrule—Mechanically Transferable Ferrule
A resin-molded part with high-precision holes for fiber alignment to connect multiple optical fibers all at once.

MPO connector—Multifiber Push-On Connector
A connector with a MT ferrule to connect easily.

2. Structure

2.1 Structure of the hardened optical connector

Figures 3 and 4 show the exterior structure of the developed hardened connector. The connector structure is based on a multi-fiber optical connector[4)], and the hardened connector achieves simple and quick connector connection by the bayonet lock method.

All the main components of the connector are made of plastic instead of metal, the hardened plastic is selected and the connector structure is optimized to achieve the economic efficiency, robust mechanical properties and outdoor applicability.

The ferrule position at the connector tip is shown in Fig. 5. By groping fitting work on the Plug-Receptacle connection, the end face of the ferrule might be damaged, so the ferrule is placed inside the connector housing to protect the end face of the ferrule. Further more, the grinding length of the ferrule is longer than the conventional MPO connector; the mating length of the MPO connector is 5.7 mm, but the developed connector has a mating length of 10.5 mm (Fig. 6 (a)). This design can help the ferrule from interfering the plug connector housing or the receptacle connector housing even when the connector is inserted at an angle (Fig. 6 (b)). Therefore the hardened connector can be connected stably without any damage to the connector even in an unstable environment outdoors.

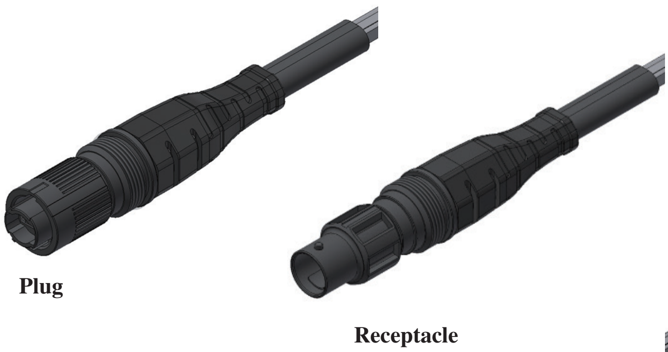

Fig. 3. Appearance of hardened connector.

Fig. 4. Appearance of hardened connector (At mating).

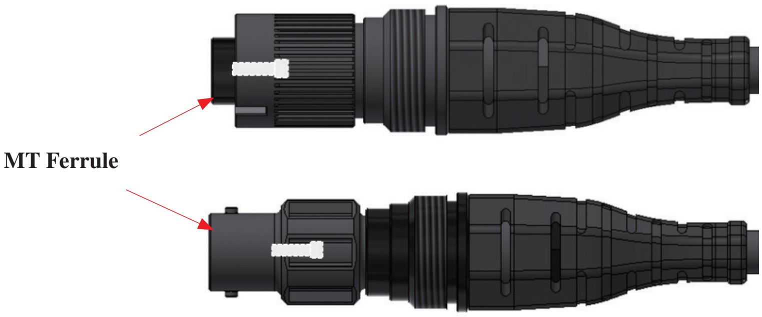

Fig. 5. Ferrule Position.

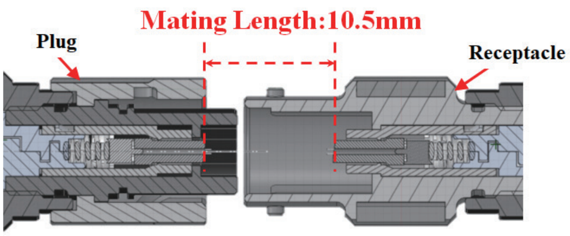

Fig. 6(a). Mating length of hardened connector.

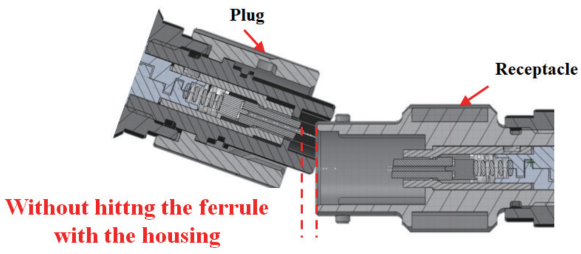

Fig. 6(b). Designed to prevent interferences between the ferrule and the housing.

2.2 Design of Sealing Structure

There are two sealing structures at the hardened connector. First, to seal the gap of the housing components, an O-ring is located between the housing components. Second, to seal the gap between the connector housing and the cable, a heat-shrinkable tube is located over the connector housing and the cable.

Fig. 7. Sealing structure.

2.3 Applicable Cable

Figure 8 shows the cable structure applied to this connector[5]. By applying SWR™/WTC™ technology, the cable achieved smaller diameter and lighter weight, and also it is easy that the cable after laying is branched at the intermediate point. Figure 9 (b) shows the work scene during the connector towing. Since the outer diameter of the towing cap is less than 21 mm as shown in Fig. 9 (a), the cable provides excellent cable traction in overhead conduits.

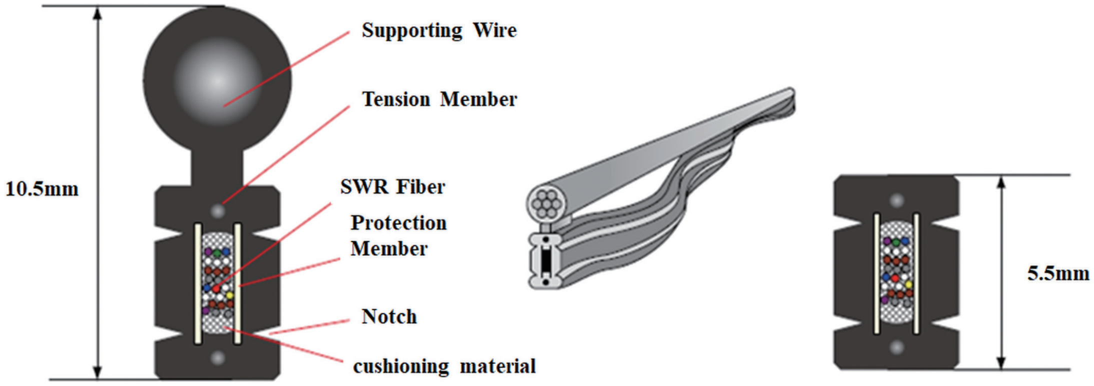

Fig. 8. 24-fiber aerial distribution optical cables [5].

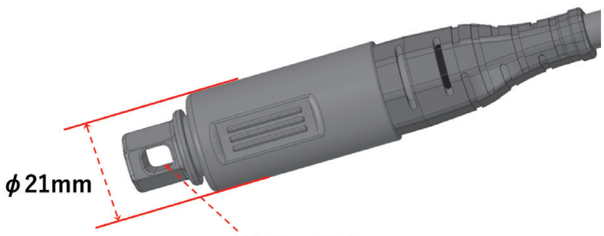

Fig. 9(a).Bird-eye view of the pulling-cap with connector.

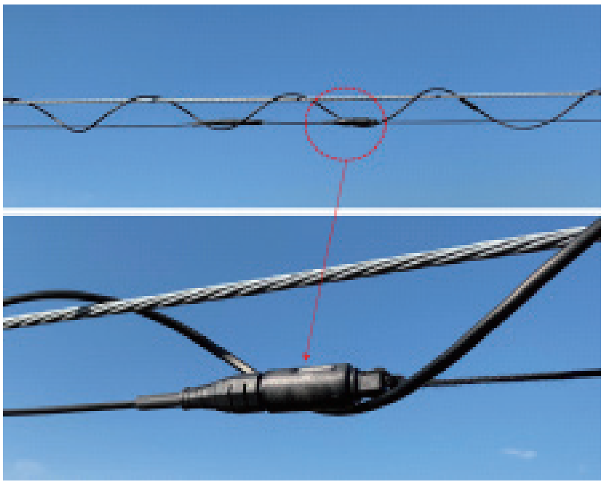

Fig. 9(b). Connector pulling.

3. Characteristics of the Hardened Optical Connector

3.1 Optical Properties

Figures 10 and 11 show the results of the connection loss(IL) and reflection attenuation(RL) of the hardened optical connector. IL and RL were measured at two different wavelengths; 1310 nm and 1550 nm.

Especially measured by 1310 nm wavelength, IL average is 0.12 dB and IL maximum is 0.33 dB. The RL of all fiber points are more than 55 dB. So this connector achieves excellent optical properties.

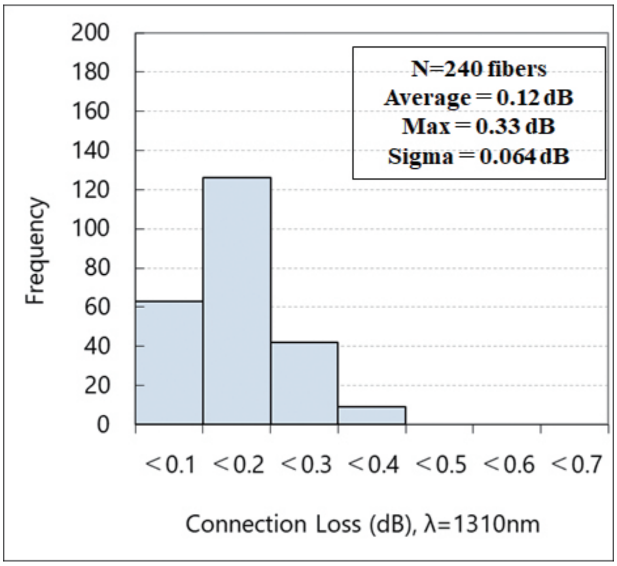

Fig. 10(a). Connection loss of hardened connector at 1310nm.

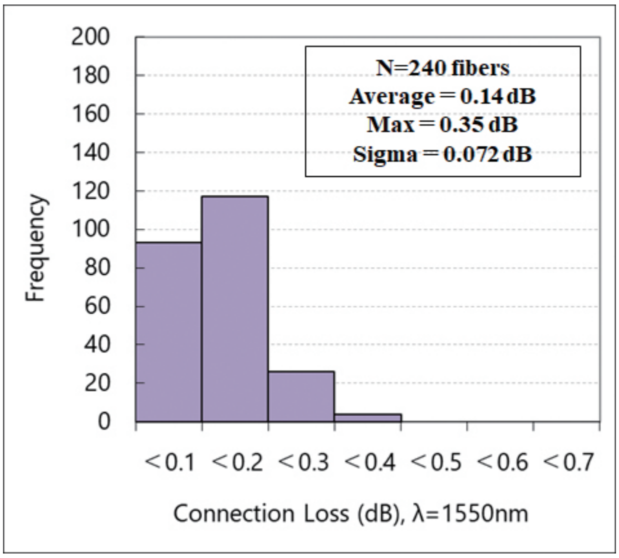

Fig. 10(b). Connection loss of hardened connector at 1550nm.

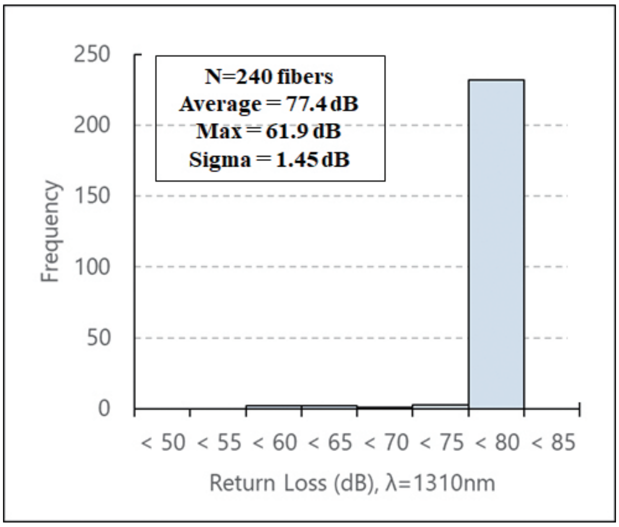

Fig. 11(a). Return loss of hardened connector at 1310nm.

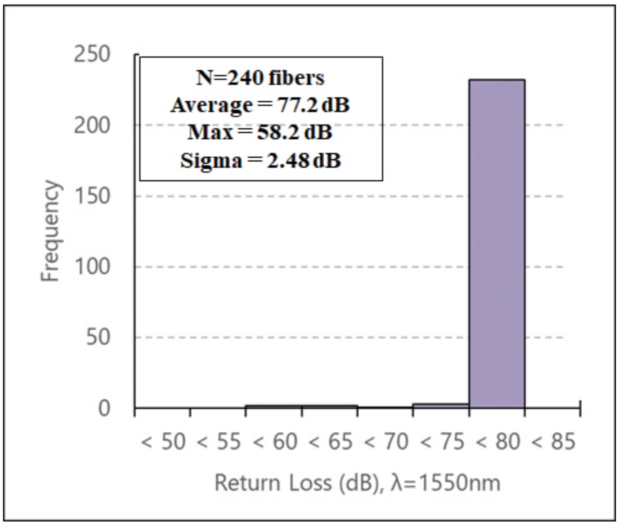

Fig. 11(b). Return loss of hardened connector at 1550nm.

3.2 Reliability Test

Table 1 shows the list of reliability tests for this connector. The IL variation after test was less than 0.30 dB at all tests.

Figure 12 shows a graph of the connection loss during the temperature cycle test, as an example of the environmental test results. This figure contains the measurement data for 8 of the 24 channels on one connector and temperature data, which "CH" indicates "channel", "TEMP" indicates "temperature".During the test, the IL variation was less than 0.17 dB at all cycles.

Therefore this hardened connector achieved stable reliability characteristics.

Table 1. Mechanical test result.

	Item	Test conditions	Evaluation Results
Mechanical properties	Tensile Properties	200 N, 1 min	0.19 dB maximum after test
	Traction characteristics	450 N, 1 min	0.15 dB maximum after test
	Bending resistance	9.8 N, +/- 90 degrees x 10 repetitions	0.20 dB maximum after test
	Vibration resistance characteristics	Time: 0.5 h x 3 axes, Total amplitude: 1.5 mm, Frequency: 10 ~ 55 to 10 Hz/min	0.29 dB maximum after test
Environmental characteristics	Temperature cycle characteristics	-25 ~ +70 ℃, 3 h/cyc, 300cyc	Test loss variation 0.17 dB or less
	Wet heat properties	+70 °C, 90 %RH, 500 h	Test loss variation 0.17 dB or less
	Low-temperature characteristics	-25 °C, 500 h	Test loss variation 0.17 dB or less

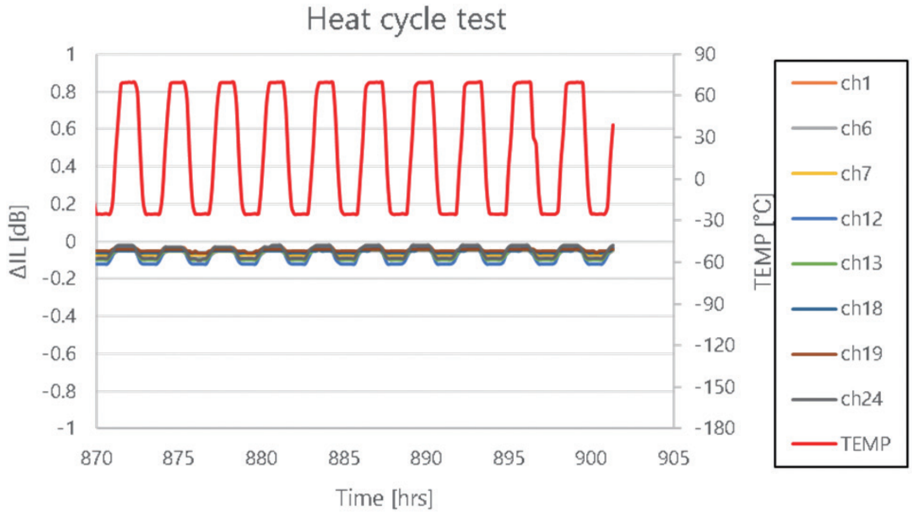

Fig. 12. Temperature cycle test results.

Table 2. Water Resistance Test.

Item	Test conditions	Evaluation Results
Water Resistance	Depth 1 m x 30 min a) Conducted after temperature-cycling b) Conducted after all mechanical test	No water intrusion

3.3 Water Resistance Test

Table 2 shows the water resistance test result of this connector. Water Resistance Test was conducted by the condition; Water depth: 1 m, 30 min.

Since this connector is expected to be used outdoors, we have conducted two types of tests; a) conducted after temperature-cycling test in Table1, b) conducted after all mechanical test in Table1.

After both testes, there was no water intrusion shown in this connector.

4. Conclusion

In this paper, we have explained about the structure, optical properties, mechanical properties, and reliability and we propose a quicker and easier connecting method by using this connector

In the future, we will continue to develop simpler and smaller hardened optical connectors and contribute to the spread of various optical infrastructure networks such as 5G.

Reference

1) G.Taki, et al.: “Highly-functional Drop/Indoor Optical Cables Supporting Fiber to the Home Networks”, Fujikura Technical Review, No.45, pp.18-23, 2015.
2) Y.Ninomiya, et al.: “New Core Alignment Fusion Splicer”, Fujikura Technical Review, No.50, pp.14-17, 2020.
3) T.Matsuda, et al.: “Optical Connector for 5G Base Station”, Fujikura Technical Review, No.51, pp.35-38, 2022.
4) S.Kanno, et al.: “Multi-fiber connector for high-definition video equipment”, Fujikura Technical Review No.127, pp.22-27, 2014.
5) T.Fukute, et al.: “Ultra-High-Density Aerial Distribution Optical Fiber Cables for Rural Area FTTH Network”, Fujikura Technical Review, No.126, pp.44-47, 2014.