WAKA KOTAHI
NZ TRANSPORT AGENCY

OPTICAL FIBRE

ITS Design Standard

30 JUNE 2020
1.0

New Zealand Government

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More information

If you have further queries, contact the ITS S&S Coordinator via email: itsspec@nzta.govt.nz

More information about intelligent transport systems (ITS) is available on the Waka Kotahi website at https://www.nzta.govt.nz/roads-and-rail/highways-information-portal/technical-disciplines/intelligent-transport-systems/

This document is available on the Waka Kotahi website at https://www.nzta.govt.nz/resources/intelligent-transport-systems/its-standards-and-specifications/

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Contents

1 DOCUMENT CONTROL

1.1 Document information

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1.2 Document owner

Role ITS Document Review Panel
Organisation Waka Kotahi

1.3 Document approvers

This table shows a record of the approvers for this document.

Approval date	Approver	Role	Organisation
DD/MM/YY		Design Engineer	Waka Kotahi
		Product Manager	Waka Kotahi
		Asset Manager	Waka Kotahi
		Safety Engineer	Waka Kotahi
		Security Specialist	Waka Kotahi
		Technical Specialist (Technology Operations)	Waka Kotahi
		Procurement Manager	Waka Kotahi
		Journey Manager (Transport Operations)	Waka Kotahi

1.4 Version history

This table shows a record of all changes to this document:

Version	Date	Author	Role and organisation	Reason
0.1	29/09/10	Tom Harris	Senior Design Engineer, WSP Opus	ITS draft specifications issue
0.2	25/01/11	Jamie French Tom Harris	Beca Senior Design Engineer, WSP Opus	AMA specifications review
0.3	10/01/12	Paul Addy	Technical Principal, Transport Technology, WSP Opus	Updates following consultation
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0.7	02/06/20	Final Word	Editorial services	Transferring draft document to latest ITS design standard template
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2 TERMINOLOGY USED IN THIS DOCUMENT

Term	Definition
DRAFT	The document is being written and cannot be used outside of Waka Kotahi
PENDING	The document has been approved and is pending ratification by Waka Kotahi. It can be used for procurement at this status
RATIFIED	The document is an official Waka Kotahi document. Road controlling authorities are obliged to follow a document with this status
RETIRED	The document is obsolete, and/or superseded
ABF	Air-blown fibre
Absorption	That portion of fibre-optic attenuation resulting from the conversion of optical power to heat
Adaptor	A mechanical device designed to align fibre-optic connectors
Air blowing	Method of installing loose-tube fibre into a standard duct, or of installing micro and mini cables into a microduct using air to reduce friction
AS/NZS	Australian/New Zealand standard
Attenuation	The reduction in optical power as it passes along a fibre, usually expressed in decibels (dB)
Attenuator	A device that reduces signal power in a fibre-optic link by inducing loss
Backscatter	The scattering of light in a fibre back toward the source, used to make OTDR measurements
Bend radius	The radius of curvature that an optical fibre can bend without sustaining damage
Bit	An electrical or optical pulse that carries information
Buffer	A protective coating applied directly on the fibre
Cable	One or more fibres enclosed in protective coverings and strength members
Chamber	An enclosure used to provide space for the management of cables and associated equipment
Cladding	The lower refractive index optical coating over the core of the fibre that traps light into the core
Connector	A device that provides for a demountable connection between two fibres or a fibre and an active device and provides protection for the fibre
CoPTTM	Code of practice for temporary traffic management. The Waka Kotahi CoPTTM describes best practice for the safe and efficient management and operation of TTM (temporary traffic management) on all roads in New Zealand
Core	The light-conducting centre of an optical fibre, defined by the region of high refractive index
Coupler	An optical device that joins two connectors to allow the cores to be aligned with minimal light loss

Term	Definition
Dark fibre	Fibre cores that are not normally used, but are used when switched-in by a failure on the network – effectively redundant fibre pairs or a redundant ring
DAS	Distributed acoustic sensing systems
dB	Decibel, a unit of measurement of optical power which indicates relative power on a logarithmic scale, sometimes called dBr. dB=10 log (power ratio)
dBm	Decibel milliwatts, a unit of measurement of optical power referenced to 1 milliwatt
Detector	A photodiode that converts optical signals to electrical signals
Digital	Signals encoded in discrete bits
Dispersion	The temporal spreading of a pulse in an optical waveguide. May be caused by modal or chromatic effects
Duct	Parts of a closed wiring system used to enclose cables and electrical telecommunication installations. Allows cables to be drawn in, blown in or replaced
EN	European standard
End face	Term often used to describe the end of a ferrule. The end face is finished or polished to have a smooth end, which can minimise connector loss or back reflection. Typical polish types are PC, UPC and APC
FC connector	Fixed connection. It is fixed by way of a threaded barrel housing
Ferrule	A precision tube which holds a fibre for alignment for interconnection or termination. A ferrule may be part of a connector or mechanical splice
Fibre identifier	A device that clamps onto a fibre and couples light from the fibre by bending, to identify the fibre and detect high-speed traffic of an operating link or a 2kHz tone injected by a test source
Fibre-optics	Light transmission through flexible transmissive fibres for communications or lighting
FIST	Fibre infrastructure system technology
FOSC	Fibre-optic splice closure
Fusion splicer	An instrument that splices fibres by fusing or welding them, typically by electrical arc
GBIC	Gigabit interface converter. Gigabit networking, or commonly called 10-Gigabit Ethernet (10GBASE-T), is a communications technology that offers data speeds up to 10 billion bits per second
IEC	International Electrotechnical Commission standard
Index of refraction	A measure of the speed of light in a material
Index-matching gel	A liquid with an index of refractive similar to glass used to match the materials at the ends of two fibres to reduce loss and back reflection
Insertion loss	The loss caused by the insertion of a component such as a splice or connector in an optical fibre

Term	Definition
ISO	International Organization for Standardization standard
ITU-T	ITU Telecommunication Standardization Sector standard
Jacket	The protective outer coating of the cable
Jetting	Method of installing cables using water to reduce friction
Jumper cable	A short, single-fibre cable with connectors on both ends. Used for interconnecting other cables or testing
Launch cable	A known good fibre-optic jumper cable attached to a source and calibrated for output power, used as a reference cable for loss testing
LC connector	LC stands for lucent connector. The LC is an SFF (small-form factor) fibre-optic connector
LD	Laser diode, a semiconductor device that emits high powered, coherent light when stimulated by an electrical current. Used in transmitters for SM (single mode) fibre links
LED	Light-emitting diode, semiconductor device that emits light when stimulated by an electrical current. Used in transmitters for MM (multimode) fibre links
Link, fibre-optic	A combination of transmitter, receiver and fibre-optic cable connecting them, capable of transmitting data. May be analogue or digital
Lock-and-block resin	Two-part epoxy resin used to lock and block fibre inside the FIST/FOSC closure
Macrobending	Macrobending occurs when optical fibre is bent into a visible curvature
MBR	Minimum bending radius
Mechanical splice	A semi-permanent connection between two fibres made with an alignment device and index-matching gel or adhesive
Microcable	Cable designed for air-blown installation diameter of less than 2mm. For the purposes of this document, this refers to a 12f spur cable with 12 fibres set in an encapsulating layer, providing excellent dimensional and thermal stability
Microduct	Duct with an internal diameter of 3.5mm or 10mm in which the ABF fibre is blown
Mini cable	Cable is lightweight designed for air-blown/jetting installation in microduct. For the purposes of this document, this refers to a 96f low-friction sheathed backbone cable
MM	Multimode
MM optical fibre	Optical fibre with a core diameter much larger than the wavelength of light transmitted that allows many modes of light to propagate. Commonly used with LED sources for lower speed, short-distance links
Mode	A single electromagnetic field pattern that travels in fibre
Multiduct	Microduct bundled together and encased with an outer sheath
Network	A system of cables, hardware and equipment used for communications
nm	Nanometre, a unit of measure 10–9m, used to measure the wavelength of light

Term	Definition
OF	Optical fibre, an optical waveguide comprised of a light-carrying core and cladding which traps light in the core
OFDF	Optical fibre distribution frame, a multi-purpose mechanical shelf assembly for a fibre management system in a rack environment
OLTS	Optical loss test set, a measurement instrument for optical loss that includes both a meter and source
Optical loss	The amount of optical power lost as light is transmitted through fibre, splices, couplers etc
Optical power	The amount of radiant energy per unit time, expressed in linear units of watts or on a logarithmic scale, in dBm (where 0dB = 1mW) or dB* (where 0dB* = 1 µW)
Optical return loss, back reflection	Light reflected from the cleaved or polished end of a fibre caused by the difference of refractive indices of air and glass. Typically, 4 per cent of the incident light. Expressed in dB relative to incident power
OTDR	Optical time-domain reflectometer, an instrument used to measure the time and intensity of the light reflected on an optical fibre
Patch cord	A patch cord is a fibre-optic cable used to attach one device to another for signal routing
Photodiode	A semiconductor that converts light to an electrical signal, used in fibre-optic receivers
Pigtail	A short length of fibre attached to a fibre-optic component such as a laser or coupler
Power meter, fibre optic	An instrument that measures optical power emanating from the end of a fibre
RCA	Road controlling authority. An organisation that manages roads, ie Waka Kotahi for state highways and territorial authorities for other roads.
Receiver	A device containing a photodiode and signal conditioning circuitry that converts light to an electrical signal in fibre-optic links
Refractive index	A property of optical materials that relates to the velocity of light in the material
SC connector	Subscriber connector, a general-purpose push/pull-style connector
Scattering	The change of direction of light after striking small particles that causes loss in optical fibres
SFF	Small-form factor
SM optical fibre	Single-mode optical fibre, designed to carry a single ray of light (mode). This ray of light often contains a variety of different wavelengths. Commonly used with laser sources for high speed, long-distance links
SOSA	Splice only sub-assembly, a device for joining fibres. Comes in both single circuit and single element types
Source	A laser diode or LED used to inject an optical signal into fibre

Term	Definition
Splice (fusion or mechanical)	A device that provides for a connection between two fibres, typically intended to be permanent
ST connector	Straight- tip connector, a bayonet-style optical-fibre connector
STMS	Site traffic management supervisor, a Waka Kotahi-qualified person who has specific responsibility for documentation and management of TTM (temporary traffic management)
Talk set, fibre optic	A communication device that allows conversation over unused fibres
Termination	Preparation of the end of a fibre to allow connection to another fibre or an active device, sometimes also called 'connectorisation'
Test cable	A short, single-fibre jumper cable with connectors on both ends used for testing. This cable must be made of fibre and connectors of a matching type to the cables to be tested
Test source	A laser diode or LED used to inject an optical signal into fibre for testing loss of the fibre or other components
TMP	Traffic management plan, a document describing the design, implementation, maintenance and removal of TTM while the associated activity is being carried out within the road service or adjacent to and affecting the road service
TOC	Traffic operations centre
Transmitter	A device which includes an LED or laser source and signal-conditioning electronics that is used to inject a signal into fibre
TTM	Temporary traffic management
Visible light source	An instrument that couples visible light into the fibre to allow visual checking of continuity and tracing for correct connections
Watts	A linear measure of optical power, usually expressed in milliwatts (mW), microwatts (µW) or nanowatts (nW)
Wavelength	A measure of the colour of light, usually expressed in nanometres (nm) or microns (µm)

3 OVERVIEW AND OUTCOMES

This section defines the operational outcomes for intelligent transport systems with respect to the transport network.

3.1 ITS design standard definition

Design assurance is delivered through a series of design standards. The standards ensure road network level operational outcomes and design for safety, security and maintainability are accounted for in solutions being delivered to Waka Kotahi. Design standards address risks typically generated at the front end of roading or infrastructure projects. Their objective is to ensure solutions address the correct operational need and solutions are fit for purpose.

3.2 System overview

ITS equipment located alongside motorway and expressway standard state highways is increasingly connected to a fibre-optic backbone. Some sections of the state highway network in New Zealand have Waka Kotahi fibre-optic cable connecting Waka Kotahi ITS assets and local transport authorities' ITS assets to traffic operations centres (TOCs). ITS assets connect to ITS roadside control cabinets which have a local fibre connection to the fibre backbone in the nearest ITS backbone jointing chamber. As a direct result of this there is a need to provide a set of guidelines for the supply, installation, testing and management off fibre-optic cable by contractors to ensure that best practices are followed.

3.2.1 System definition

Optical fibre is a critical utility for providing both discrete devices or equipment, and trunk or backhaul communications and connectivity for ITS. The trunk or backhaul support mass connectivity of roadside field equipment to back office command and control systems and support interfacility communications between traffic control centres. Discrete device connectivity is supported through equipment connection nodes which are connected to the trunk network. Optical fibre is also used for traffic detection purposes and the requirements to support this are part of this design standard.

3.2.2 System class

008 Communications infrastructure.

3.3 Scope

The purpose of this document is to specify the requirements for the ITS backbone and local optical fibre single mode supply and installation.

This design standard provides contractors with requirements set by Waka Kotahi for supply, installation, testing and management of fibre-optic cable and related peripherals. Any exceptions to the recommendations made herein must be approved by Waka Kotahi.

3.4 Applicable legislation

To be defined.

3.5 Outcomes

To be defined.

3.5.1 Operational

To be defined.

3.5.2 For road users

To be defined.

3.5.3 For road controlling authorities

To be defined.

4 DESIGN FOR OPERATION

This section defines the functionality required to achieve successful operation of the intelligent transport system.

4.1 Design drawings

Site-specific detailed design drawings for all fibre routes and jointing details shall be provided for review to Waka Kotahi prior to commencement of installation.

The fibre shall be shown in the schematic drawings with the state highway route position increasing from left to right and the joint, cable and cabinet numbers recorded as per section 4.7 Labelling of cables and equipment in this document.

4.2 Fibre cable

The optical-fibre network shall use high quality all dielectric, loose tube optical-fibre cable or ABF mini cable with dry or flooded water barrier that is suitable for underground installation.

The fibre cable shall have a minimum of 40 years' design life.

The fibre shall meet or exceed the latest ITU-T recommendation G.652.D-2009.

The following characteristics shall apply to all cable used for the network:

- single-mode 1550nm low-dispersion fibre
- attenuation at 1310nm not to exceed 0.4dB/km
- attenuation at 1550nm not to exceed 0.3dB/km

4.2.1 Fibre types

4.2.1.1 Single-mode loose tube

Fibre transmission between nodes (referred to as the fibre backbone) is to be over single mode loose-tube fibre or air-blown fibre (ABF) mini cable.

Figure 1. Single mode loose-tube fibre.

4.2.1.2 Air-blown single-mode microfibre

May be used as an alternative to loose-tube fibre. It must be installed in the appropriate microducting.

For identification purposes, within this document, 96 core ABF is referred to as mini cable and 12 core referred to as microcable.

The microcable is the result of bringing together multiple optical glass fibres (OFs) to form a single unit, which must be handled as one piece.

- Construction of the fibre unit will be multiple OFs set in a strippable buffer layer, which in turn is encased by a polyolefin sheath that has been treated with low-friction antistatic compound.
- The buffer layer must provide excellent dimensional and thermal stability.
- To ensure contamination-free termination and fast installation, the fibre unit must be free from carbon powders or any form of gels.
- The fibre unit must be able to be identified with visible metre markings, fibre type and manufacturer information on the outer surface (polyolefin sheath).
- The fibre themselves, in the fibre unit, will comply with performance standards, as discussed and directed by the ITU standards. Variants of OM1, OM2, OM3 and SM will be available.
- Minimum bending radius (MBR) shall be 50mm for two and four-fibre units; 80mm will apply for the eight and 12-fibre unit. MBR will apply to OM1, OM2, OM3 and single-mode variants of the microduct.

4.2.1.3 Blow system compatibility

Compatibility refers to the microcable and the primary tube's inherent design features to provide superior blow speed and distance. It is generally agreed that the lower the combined drag coefficient of the fibre unit and the primary tube, the faster and longer the fibre unit can be deployed.

Blowing distances exceeding 1500m, without the need to recoil and re-blow, should be able to be achieved.

The fibre core count to be used for each project or works is to be approved by Waka Kotahi.

4.2.1.4 Multimode

The use of multimode (MM) fibre must be approved by Waka Kotahi and may only be used to connect local peripheral equipment

4.2.2 Fibre colour

The New Zealand colour coding is as follows (note that certain types of fibre from different countries may have a different colour code).

The following diagram shows fibre numbers and respective colours:

Figure 2. Fibre colour coding.

4.2.3 ITS backbone fibre-optic cable

Within urban areas, the ITS backbone fibre-optic cable along the highway shall have as a minimum 96 single-mode fibre cores.

In rural areas, a 96f fibre-optic cable is desirable, but a 48f cable may be used if circumstances dictate.

4.2.4 Local fibre connection cable

A local fibre-optic cable connecting an ITS fibre interface Ethernet switch installed inside a roadside control cabinet and the fibre backbone cable in a fibre jointing chamber (or fibre jointing cabinet which may be used in an ABF network) nearest to the roadside control cabinet shall be SM 12 core fibre-optic cable. The use of ITS fibre interface Ethernet switches is subject to the approval of the Waka Kotahi Fibre Change Control Manager.

4.2.5 Distributed acoustic sensing fibre requirements

The ground conditions at the installation site will also have an impact on the cable construction selection and whether a conduit or armour is required.

For monitoring purposes, distributed acoustic sensing (DAS) requires good acoustic coupling between the fibre, the cable layers and the outside environment to ensure the best response of the system. In order to achieve this, the preferred cable construction is as follows:

- gel-filled loose tube
- single armour
- single jacket
- one dark fibre core.

Cables that are used for communications are generally suitable for DAS.

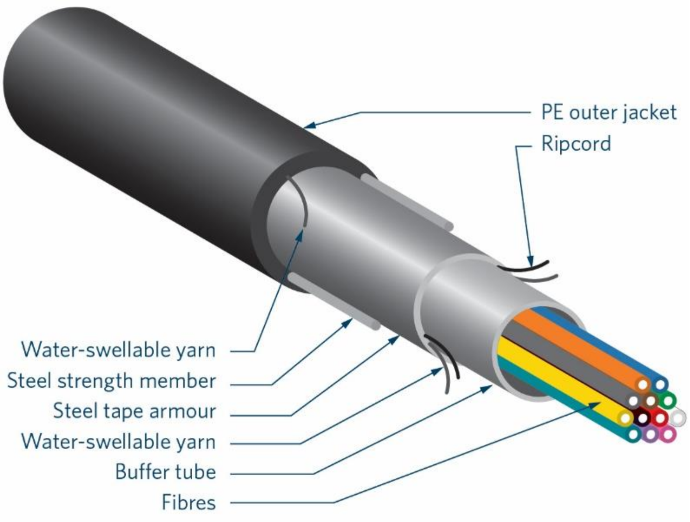

Figure 3. Typical construction of a general-purpose cable.

Note that dry-powder fill hygroscopic cables may reduce the acoustic coupling to the fibre and should only be used with caution and after consultation. These may still be used for DAS and often the reduction in sensitivity can be used to positive benefit by screening out background nuisance alarms. The effective range of such cables will often be reduced as compared to a gel-filled loose-tube arrangement.

4.2.5.1 High-performance cables for distributed acoustic sensing

System performance can be enhanced by utilising cables such as a flat dipole cable, ribbon cable or a tight-buffered tactical cable. OptaSense® will consult on whether a high-performance cable is required, for example in particular security applications where enhanced detection ranges are required or where there is a significant offset between fibre and railway.

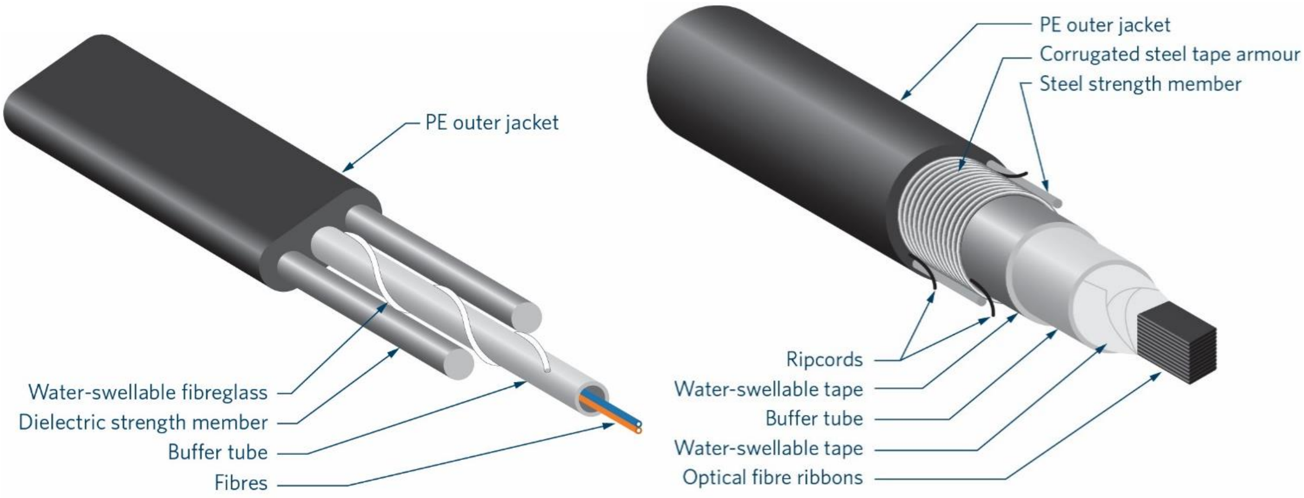

Figure 4. Dipole cables, ribbon cables and tight-buffered cables (not shown) can, with the correct design, offer a sensitivity gain over conventional cables.

4.3 Fibre network components and equipment

4.3.1 Equipment housing

4.3.1.1 Cabinets

All cabinet housing fibre racks, equipment, pigtails and any other related fibre equipment should be physically secure and weatherproof and shall be in accordance with the latest version of ITS delivery specification: Roadside cabinets.

4.3.1.1.1 Fibre jointing cabinet

This is generally used by ABF and shall meet the following requirements:

The cabinet shall:

- have a minimum design life of 25 years
- be a commercially available model
- have a three-point locking mechanism in common with the latest version of ITS delivery specification: Roadside cabinets
- be IP 65 rated, as per EN 60529.
- be suitable for multi-fibre management.
- have a secure anchor for incoming loose-tube cables within the cabinet enclosure.
- be suitable for different cable diameters.

- be suitable for ABF and conventional fibre.
- be constructed of aluminium or galvanised steel to protect against corrosion.

Plastic cabinets shall not be used unless they are certified by the manufacturer to remain structurally sound in New Zealand UV conditions for the design life of the cabinet.

The cabinet shall be 100 per cent rodent and insect proof.

Doors shall be recessed and shall not have exposed hinges.

4.3.1.2 Fibre connectors

The interface to the Waka Kotahi fibre network shall be a pair of fibre pigtails spliced into the main fibre run with a pair of SC or LC connectors (depending on the design). Other connector types are acceptable where:

- existing equipment dictates the use of a specific type, such as FC; or
- there is a specific ITS requirement for specialist equipment.

Any variation to this must be clearly documented on any as-built diagrams or schematics.

4.3.1.3 Peripheral equipment fibre connection cable

MM fibre-optic cable may only be used to connect local peripheral equipment to a roadside control cabinet.

AWS fibre cabling and connections:

- The fibre cables at the signal control cabinet shall be terminated in a fibre termination box installed within the cabinet, one tray per cable.
- Each of the incoming signal control cabinet cables shall be spliced to a fibre patch cord with the joint carefully curled onto a tray for protection.
- The patch cords from the signal control cabinet fibre termination box shall be connected to the signal controller AWS interface unit.

The fibre cables at the AWS shall be terminated in a fibre wall-mounted tray inside the AWS pole box.

4.3.1.4 Patch cords

Patch cords used to connect the Waka Kotahi fibre to equipment should be 3mm, except when connector type dictates otherwise, such as with LC connectors.

Note: Typically, patch cord fibre is offered in either 2mm or 3mm jacket. The 3mm jacket offers more protection against mechanical damage and over bending. Most SM fibre cord utilises bend-insensitive G.657 glass which is no longer prone to this problem.

4.3.2 Cable protection

All duct and duct formations entering a structure shall be constructed in a manner that prevents the ingress of water, gas etc from entering the structure around the ducts, ie the ducts are permanently fixed and sealed.

Where cables are to be stored below ground level, underwater or onto a solid structure such as a rock face or bridge, the minimum ground cover required is as follows:

Cable laying scenario	Minimum ground cover (mm)
Existing communication ducts	450
New duct/microduct lines in rural areas or alongside non-kerbed roads (ie where there is a possibility of road reforming or grading of the road edge)	600
New duct/microduct lines in stable, well-formed suburban areas	600
Direct-buried copper cables in footways and berms	450
Direct-buried copper cables in roadways	600
Direct-buried fibre cable	1000
Fibre for distributed acoustic sensing (median)	130

4.4 Closure preparation

4.4.1 Closures

Closures are to be installed as per manufacturer's instructions.

Access point type closures (ie FISTs) are to be used for all backbone joints, unless otherwise approved by Waka Kotahi. For demarcation purposes, all backbone fibres are to be terminated on one side of the closure and spur fibres on the other side. Fibres from one tube should be jointed on the same tray, except when the fibres are to be connected to a spur.

Backbone fibres are to be terminated on the 'O' (odd-numbered ports) side of the base of the closure, using the single element trays. Spur fibres are to be terminated on the 'E (even-numbered ports) side, using the single circuit trays. However, the cables can enter the closure via any port.

In the event that only two ports are left free on the base of a FIST-type closure, a multi-drop cable kit is to be fitted on these remaining ports, to allow extra capacity at a later date.

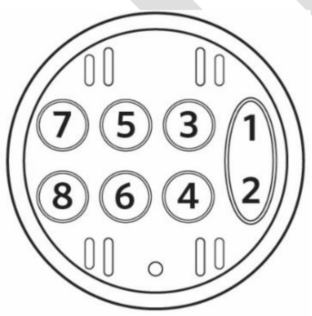

Figure 5. Underneath view of a closure base (with numbers added).

4.4.2 Lock and block for ABF systems

A lock-and-block resin and stem or fibre-grip product is to be fitted to the ends of each microduct inside the FIST closure to prevent fibre creep and water intrusion via the microduct.

4.4.3 Splicing tray management

Tubes should enter from opposing sides of the splicing trays to prevent any crossover of fibre upon trays. Tubes must allow for tray movement for access to lower trays.

There should be a minimum of 1250mm fibre end for splicing in splicing trays.

The size of the splice protector to be used will be dictated by the type of splice tray used, ie a FIST-type splice tray will require a 45mm splice protector and a FOSC-type splice tray will require a 62mm splice protector. A splice protector must cover the fibre cladding by a minimum of 5mm.

4.4.4 Spare fibre storage

In a FIST-type closure, uncut fibres can be stored as single circuits in trays, whilst uncut tubes can be stored in the storage space between the profiles. Spare cut fibres should be stored on spare trays.

If a FOSC-type closure has been approved by Waka Kotahi, uncut fibres must be stored on a tray, whilst uncut tubes must be stored in a storage basket.

4.5 Fibre verification

4.5.1 General considerations

Fibre verification (the process of positively identifying fibre to be worked using test equipment) must be undertaken before any fibre is cut, to eliminate avoidable disruption to the network and to Waka Kotahi customers.

When undertaking work on the fibre network, contractors must ensure that their employees are supplied with the appropriate test equipment. The equipment to be used must be suitable for the length of the fibre to be tested.

4.5.2 Verification equipment and techniques

There are a number of fibre verification techniques using various types of equipment, such as:

- optical time-domain reflectometer (OTDR)
- light source and power meter
- live fibre identifier
- visible light source
- optical talk set.

4.5.3 Macrobending

Macrobending is a verification technique which should only be used as a last resort when all other positive identification is unavailable. If it has to be used, all care should be taken to ensure the macrobending does not jeopardise the physical integrity of the fibre. Bending should be as close as practicable to the splice protector, or in the middle of the fibre loop so that a splice can be easily created should the fibre break.

Optical loss is cumulative so a number of small bends can accomplish the equivalent of one very sharp (and risky) bend. Where possible, use multiple small bends to create the required high loss (ie wrapping the fibre around a small finger several times). If the fibre is part of a working system, the macrobend(s) will trigger an alarm condition.

4.5.4 Fibre verification procedure

1. Check the details of the Waka Kotahi fibre-optic cable change request form, which will specify the cable and fibres to be used.
2. Notify Waka Kotahi and/or other affected parties of the intention to commence work.
3. Establish communication between the work site and the test site.
4. At the test site, uncap the fibre to be tested and connect it to the testing equipment.
5. Turn on the testing equipment and request the work site party to check for condition on the appropriate fibre.
6. Obtain positive identification that the fibre is the one to be worked on.
7. When the fibre has been positively identified it should be immediately cut and/or labelled to avoid confusion if it is not immediately worked on or if there are more fibres to be worked on.
8. Repeat for all subsequent fibres to be tested.
9. Upon completion of testing, restore connection of fibres or recap.
10. When work is completed, confirm with Waka Kotahi and/or other relevant parties that the affected systems are working properly.

4.6 Fibre splicing rules

The fusion splicing shall be carried out in a clean environment. Use the slack 20m coil to move the splice enclosure to a location out of the jointing chamber and into a suitable area for fusion splicing.

The fusion splices shall have an attenuation no greater than 0.1dB at 1550nm and 1310nm.

Splices that fail to meet the criteria shall be removed and respliced until a satisfactory result is achieved.

All fibre should be jointed using fusion splicing. The splices are then protected with a heat-shrink splice protector and placed on a splice tray where the splice is held and spare fibre managed.

Mechanical splicing is only acceptable for temporary fault restoration.

When fibre splicing, the fusion splicer estimates the loss of the splice. This is only an estimation, therefore all splices should be checked with an OTDR and any splice with an estimation of 0.05db or more should be respliced as a precaution. The actual splice loss verified with the OTDR should be no more than 0.1db. If the fibre is respliced more than four times to try to achieve this maximum loss, then the fibre should be deemed as a mismatched fibre and the best loss accepted but noted.

4.7 Labelling of cables and equipment

4.7.1 Use of K-type cable marker system for cables

Microfibre cables cannot be labelled due to their small size and the fact that they are generally not exposed, so for labelling purposes a microduct containing a microfibre shall be treated as a cable.

All cables in chambers and cabinets must be labelled using K-type cable markers and carrier strips (ie Critchley, Partex or similar). The carrier strips must be secured to the cable using stainless-steel tab cable ties.

Figure 6. Example of a labelling tag.

4.7.2 Labelling of cables

For fibre cable labelling nomenclature, refer to section 3.3 ITS fibre-optic cable numbering in the latest version of ITS core standard: General requirements.

4.7.3 Labelling of closure domes

Fibre enclosures shall be labelled using the 3M Non-Reflective Lettering System.

The labelling of the enclosure must include, in the following order:

1. the letter ‘J’ for joint
2. state highway number ‘001’ for SH1, ‘016’ for SH16
3. current chamber ID
4. direction of adjacent traffic flow – north, south, east or west..

Refer to section 3.3 ITS fibre-optic cable numbering in the latest version of ITS core standard: General requirements.

Figure 7. Dome labelling example: J-001-5050-S.

4.7.4 Labelling of splicing trays

The method for labelling splices and trays will depend on the type of closure used. However, regardless of type of trays in use, all fibres or trays must be labelled to allow easy identification of splices.

All trays should be numbered starting from the bottom up. contractors are to follow the manufacturer's instructions on labelling of trays and splices.

4.7.5 FIST closures

The tray labels in FIST-type closures should be notated with a fine-tip permanent marker pen. If a mistake is made or the label needs to be changed at a later date, isopropyl alcohol can be used to remove the existing label.

Trays should be marked as follows (see figure 8 below):

- tray position number
- fibre section IDs
- fibres spliced.

Note that trays should be numbered according to their position on the mounting frame, and not according to the number of trays actually used. This allows for the correct numbering of additional trays that may be inserted at a later date.

Figure 8. FIST tray labelling example.

Figure 9. Tray mounting system layout.

4.7.6 FOSC closures

Splices in FOSC-type closures should be labelled with the wraparound labels that are generally provided with this type of enclosure, and the trays should be labelled with the stickers provided, always starting in numerical order from the bottom tray working upwards.

4.7.7 Labelling of OFDFs

OFDFs and patch cords should be labelled as follows:

- section and cable ID
- number of the backbone fibre used
- equipment designation.

OFDF labelling example: CMJ-01, 19 to C-001-0720-N, 20 & 21 to V-001-0650-N

The following table shows the prefixes used to identify typical equipment:

Prefix	Equipment	Prefix	Equipment
C	CCTV camera	N	Network node
D	Vehicle detection site (VDS)	OH	Over-height vehicle detector
E	Equipment cabinet	P	Pull pit
F	Fixed camera	R	RMS VMS
G	Emergency access gate	SL	Ramp signal loops
J	Jointing pit	V	Variable message signs (VMS)
L	Lane control signal		

4.7.8 Fibre-optic cable chambers

For fibre-optic cable chambers labelling nomenclature, refer to section 3.3 ITS fibre-optic cable numbering in the latest version of ITS core standard: General requirements. The same numbering scheme shall be followed when ITS design drawings are prepared.

4.7.9 ITS backbone fibre-optic cable

For backbone fibre-optic cable labelling nomenclature, refer to section 3.3 ITS fibre-optic cable numbering in the latest version of ITS core standard: General requirements. The same numbering scheme shall be followed when ITS design drawings are prepared.

4.7.10 Local fibre-optic cables

For local fibre-optic cable labelling nomenclature, refer to section 3.3 ITS fibre-optic cable numbering in the latest version of ITS core standard: General requirements.

4.8 Testing

4.8.1 OTDR testing

OTDR testing must be done for all new cable installation, all section replacement (overlays, re-splicing existing joints) and all changes to a link (spur, lead-in and reconfiguration).

OTDR users must be familiar with trace capture and manipulation, and be able to adjust the OTDR settings to obtain the highest resolution across the total length of the link under test.

Using the OTDR auto-function is not always sufficient to produce a quality optical signature (trace) or allow detailed link or splice analysis.

All equipment that requires calibration must be maintained according to the manufacturer’s requirements. Connectors must be cleaned before mating, prior to testing, and every time a connector is moved. Either a fibre connector cleaner, or alcohol and a lint-free wipe, can be used.

The OTDR has an inherent weakness which is normally called its ‘dead zone’. When looking at a fibre signature on an OTDR, the dead zone is the area from the connector on the front of the OTDR (zero distance) to the point in the trace that can be seen as a smooth line, which can be interpreted for interrogation (splice measures etc). This point may be anything from 10m to 200m, and is dependent on the power and capabilities of the type and make of OTDR used. Ideally, a launch cable of should be used to observe the true launch of the connector at the near end. The length of the launch cable has to be longer than the dead zone of the OTDR, to be able to interpret the first connection. This cable must be made of fibre and connectors of a matching type to the cables to be tested.

The distance given by an OTDR is the optical distance, which is very different from the cable sheath distance. The optical distance takes into account every optical item in the path, eg pigtails, patch cords, bare fibre on OFDFs and closure trays, loops in manholes and pits, and the fibre stranding back and forth within the cable sheath along its length. On average, the optical distance within a cable sheath is longer than the physical sheath distance by 0.25 per cent. This may not seem like much, but over a 10km length that adds up to 25m, which is a significant amount when trying to pinpoint an exact location.

End-to-end power meter testing should be done to ensure no crossovers, as well as true attenuation levels. Test leads should be cleaned and calibrated before and after testing for an average, as environmental conditions can affect the readings.

Splice loss should be 0.1db +/– 0.05db.

Link loss tests for systems that require two fibres, eg fibre pairs, should be closely matched. Results for each fibre should be within 1db.

4.8.2 OTDR set-up parameters

Ensure the OTDR is set up correctly for the link under test – pulse width, range, resolution, wavelength, index of refraction and backscatter co-efficient are all settings that can affect the resultant trace.

- The OTDR used must have sufficient dynamic range (be powerful enough) to produce an acceptable (clear) trace over the entire fibre section under test.
- To gain the maximum OTDR launch power, the appropriate fibre connector cleaning procedure must be followed.
- Sufficient time must be taken to allow for trace averaging if an acceptable (clear) trace is to be obtained.

4.8.3 Wavelength to use

Testing should be done using both 1550nm and 1310nm, in both directions. Fibre may appear to be okay at 1310nm but may have very high losses at 1550nm.

4.8.4 OTDR traces

4.8.4.1 Trace naming

OTDR traces must be sent to Waka Kotahi in Bellcore GR-196-CORE format only.

Traces shall be saved in the following naming standard:

Item	Example
Fibre # (three characters)	015
Trace type (one character)	B for Bellcore
Wavelength (one character)	3 for 1310nm or 5 for 1550nm
Trace number (three characters)	001

Trace naming examples:

- 013B5001.sor for trace from site A to site B
- 013B5002.sor for trace from site B to site A.

4.8.4.2 Trace storage

Traces need to be stored in the following manner:

- create a directory for site A (where the fibre is going from)
- create a site B directory under site A (where the fibre is going to)
- create a cable ID directory under site B
- store the trace under this directory.

Both sets of traces, from site A and site B, need to be stored in the same cable ID directory.

Trace storage example:

- C:\ATTOMS\E-450-N\ATM-01\013B5001.sor

Where ATTOMS is site A, E-450-N is site B cabinet number, ATM-01 is the cable ID, 013B5001.sor is the file name of the trace for fibre 13.

4.8.4.3 Specific trace information

Item	Header field or fibre report	Project information require in exactly this format	Example
1	Cable ID	Cable description	ATM-01
2	Fibre ID	Fibre number	009
3	Wavelength	1310nm or 1550nm	1550
4	Origin location	Site A code	Northcote annex
5	Termination location	Site B code	E-4500-N
6	Cable code	Cable type (loose tube or slotted core) Fibre type (SM or MM)	Loose-tube SM
7	Operator	Name of OTDR user, company and date	A Smith, Prime Comms, 15-02-01
8	Comment	Project description and circuit ID	CCTV Rosedale

4.8.5 Light source and power meter test

Occasionally, a test requiring a light source and power meter may be requested by Waka Kotahi.
All test instrumentation used must be within calibration. All cords and connectors must be cleaned prior to use. The loss of test cords and connectors (if used) must be accounted for as part of the link loss calculation.

4.8.6 Cable and splice loss

4.8.6.1 Attenuation

The reduction in optical power as it passes from A to B is referred to as attenuation or loss. This loss occurs from absorption, scattering and reflection along the fibre length and is generally referred to as decibels (db).

When matching lasers or equipment to fibre links or connections, if the true power loss levels are not available then a simple calculation may be done to estimate the loss on a particular section of cable. This may be used to determine the strength of laser to be used on the connection (these figures are atypical of losses in a high-quality fibre).

The average attenuation for single-mode fibres commonly used on the Waka Kotahi network is:

- 0.22dB/km @ 1550nm
- 0.33dB/km @ 1310nm.

For single-mode loose-tube cable, the acceptable maximum individual splice loss is 0.1db.

4.8.6.2 Loss formula

The formula to use when allowing for attenuation of a circuit is as follows:

- 1550nm allow 0.2db/km of cable
- 1310nm allow 0.35db/km of cable
- allow 0.15db (0.1db +/-0.05 db) per fusion splice
- allow 0.4db per connector.

For example, a circuit connectorised at both ends being 10km in length and having seven splices along the length (including OFDF splices) may be calculated as having a potential loss of 3.85db @ 1550nm and 5.35db @ 1310nm.

4.8.7 Test results and documentation

4.8.7.1 Factory test results

The contractor shall complete testing and supply factory test results, showing attenuation at two operating wavelengths for each fibre in each cable reel. These results shall be indexed to identify where each reel was installed in the network.

4.8.7.2 OTDR test results

After installation and splicing, bidirectional testing of every single-mode fibre shall be completed using an OTDR at 1310nm and 1550nm for the complete optical path between the two endpoints being tested.

The test results shall be supplied to the engineer in hard and soft copies. Any software required to view the OTDR traces shall also be supplied.

It is expected that the test results will match the factory tests for the cable reels that have been installed.

In the event that the test results indicate point discontinuities at locations other than splices, or that the installed fibre links do not meet the attenuation requirements defined herein, it shall be the contractor's responsibility to correct the problem.

4.8.7.3 Jointing chamber documentation

For every jointing chamber in which the contractor has accessed a splice enclosure a fibre audit sheet shall be supplied to the engineer in hard and soft copies, identifying all the fibre connections in the spice enclosure by fibre number, cable label number and cable direction in the jointing chamber. Fibre-optic cables in the chamber but not spliced shall also be identified.

This fibre audit shall be accompanied by a jointing chamber fibre schematic diagram certified as 'as-built' by the contractor and photographs of the interior of the jointing chamber before and after completion of the fibre splicing and recoiling of the ITS backbone fibre inside the chamber.

5 DESIGN FOR SAFETY

This section defines the requirements to ensure the intelligent transport system can be operated and serviced safely.

5.1 Health and safety

All ITS equipment must be designed to ensure installation and maintenance in accordance with the Health and Safety at Work Act 2015.

5.2 Safety outcomes

To be defined.

5.3 Site assessment

To be defined.

5.4 Site audit

To be defined.

5.5 System-specific safety requirements

To be defined.

5.6 Contractor responsibilities

The contractor's responsibilities include:

- providing a safe working environment for their staff
- ensuring that:
  - all staff are suitably trained in the work practices and health and safety measures to be applied during work, to protect themselves and other people
  - appropriate equipment is on hand to test for potential hazards
  - all staff are fully aware of potential work site hazards, and that any visitors to the work site are also made aware of the hazards
  - a trained site traffic management supervisor (STMS) is present at all times at work sites on level 2 and level 3 roads, ie high traffic volume motorways and state highways (refer to CoPTTM)
  - all staff are supplied with safety equipment and wear the appropriate personal protective equipment (PPE). Work on level 2 or 3 roads requires the use of a hard hat, safety glasses, reflectorised high-visibility vest/jacket and safety boots (refer to CoPTTM)
- ensuring the necessary maintenance, calibration and safe keeping of all tools, test gear, mechanical aids, vehicles etc required to undertake the work.

5.7 General work site hazards

Workers should take note of potential hazards that may be peculiar or specific to certain work sites, such as:

- broken glass from discarded bottles etc
- discarded syringes
- human and animal urine and faeces, both outside of and inside chambers
- lighting strikes during storms
- chambers being located close to steep embankments or walls etc
- falling debris
- water within chambers which may contain pathogens.

5.8 Eye safety and viewing of fibres

Treat all fibres as live.

Lasers are used as optical transmitters in single-mode cables and associated test equipment. These devices emit intense invisible electromagnetic radiation which is capable of damaging the eyes. Therefore, never look directly at an optical fibre end or connector end face with the naked eye and do not point it at other people. Do not attempt to view at a distance of less than 100mm.

Prior to using a direct viewing aid (eg video fibre inspection scope), verify that the fibre is not live by using an optical power meter or live fibre identifier.

Goggles/safety glasses should be worn when preparing and splicing fibre as fragments of fibre in the eye can blind.

When cutting fibre, do not rub hands in eyes to avoid fragments getting into the eyes.

5.9 Disposal of fibre

For health and safety reasons it is required that the disposal of any glass substance must be securely managed and pose no threat to the general public, animals or to waste transfer plant personnel. Fibre off cuts are a serious health hazard and once under the skin they are virtually impossible to locate and remove.

All fibre ends and waste lengths from the work site must be carefully placed in a sealable optical fibre off cut disposal canister, which is to then be securely sealed and disposed of in a safe manner (eg at a refuse collection bin or, if available, a hazardous substance bin).

5.10 Solvent use and disposal

Isopropyl alcohol and other solvents may be absorbed through the skin and present various health risks. They are a poison and should be treated as such. Chemicals should be kept in suitable air-tight storage containers, handled as per their instructions and disposed of in the appropriate manner.

When using approved chemicals, the guidelines/requirements of material safety data sheets (MSDS) must be available and adhered to.

Ample ventilation of the workspace is mandatory when working with isopropyl alcohol or any other chemicals.

The use of chemical strippers such as acetone, kerosene or petroleum-based products is prohibited.

Hands must be thoroughly washed with soap and warm water after handling chemicals and before eating or drinking.

Smoking when using solvents is not permitted, as they are highly flammable.

Mobile phone use in the immediate vicinity of exposed flammable solvents is not advised.

5.11 Working at height

Contractors shall, in relation to a place of work under the control of that contractor, ensure that where a worker may fall more than three metres, means are provided to prevent this.

Contractors must ensure that workers are adequately trained and have the appropriate equipment, such as ladders, harnesses, cherry pickers etc, required to undertake any work that involves working at height.

5.12 Working in confined spaces

Working in a confined space such as a chamber is a hazard in itself and must be treated accordingly.

The following outline some of the typical hazards:

- difficulty of access and egress
- poor ventilation, dangerous gases and oxygen deficiency
- dangers from traffic (pedestrian and vehicular)
- things falling into open chambers.

Contractors must ensure that employees observe the health and safety requirements for identifying and managing these hazards.

5.13 Gas testing

An evaluation of the workplace atmosphere must be performed from outside a confined space, such as a chamber, before any entry occurs. As the gases may be flammable, toxic or asphyxiating (and most likely a combination), all employees are required to observe special work practices to ensure a safe working environment. An atmospheric test must be undertaken to detect the possible presence of harmful airborne contaminants or the displacement of oxygen.

- Toxic gases can render a person unconscious or kill them.
- The amount of oxygen in the workplace may be displaced by a vapour, reducing the breathable atmosphere below safe oxygen levels, causing asphyxiation.
- Flammable gases can explode if ignited by a spark or equipment use.

Contractors must ensure that employees observe the health and safety requirements for gas testing.

6 DESIGN FOR MAINTAINABILITY

This section defines the requirements to ensure the intelligent transport system can be maintained.

6.1 Maintenance outcomes

To be defined.

6.1.1 OFDFs

Fibre is to be terminated in a 19-inch, one-rack unit (RU) shelf pivoting optical-fibre distribution frame with 24 SC connector simplex adaptor positions. Pivoting trays are preferred as they minimise movement of the feeder cable.

The side-hinged type are considered to be the most user friendly. The OFDF is only designed for two 12f cables (supplier's recommendation). They have two splice trays inside, capable of holding 12 splices each, so two 12f cables should be the maximum allowed. Inserting three or four 12f cables (because only two or four fibres from each 12f is being used) can lead to as many as eight 12f cables running from them, and is difficult to manage. In this situation, consider using multiple OFDFs or one 24f cable (of each type, SM and MM) to a joint enclosure.

MM cables and SM cables shall not be together in the same OFDF.

There is no recommendation for the type of OFDF to be used in node cabinets and a high-density 96f LC type OFDF could work in the case of a 96f backbone cable being routed directly into the node cabinet. Four 24f cables into four 1RU CO-POS OFDFs could be used if rodent attack is likely.

Figure 10. Pivoting optical fibre shelf.

6.1.2 Fibre splice (joint) enclosures for use in chambers

The splice enclosures used on the ITS backbone fibre in the jointing chambers shall be FIST-GC02 type closures.

The splice enclosures shall be mounted to a bracket on the side wall of the jointing chamber so that the cables or microduct neatly exit the bottom of the enclosure and enter into the coil formation. The MBR of the cables or microduct shall not be exceeded. The mounting bracket shall allow easy removal of the enclosure without the use of tools.

It is strictly prohibited to install more than one closure per backbone fibre cable in the same chamber.

6.1.2.1 FIST–type closures

Only FIST-type closures are to be used for backbone joints, and the size of closure will depend on the fibre count. This type of closure is preferred due to the following functions and features:

- single-ended design
- easily opened and closed
- base and dome are sealed with a clamp and O-ring system
- six or 16 round entry/exit ports for drop cables/microduct and one oval port for coiled cable
- mounting system allows for both SC (single circuit) and SE (single element) type trays.
- three sizes available – BC6, BD6, BE6.

Figure 11. FIST closure.

The following types of splice trays are to be used for backbone and spur terminations:

Fibre joint	Splice tray
Backbone fibre	FIST SE SOSA trays with 12 splices per tray
Spur fibres	FIST SC SOSA trays with four splices per tray

6.1.2.2 Closure mounting brackets

Closure brackets and fixing bolts shall be of hot-dip galvanised construction, except in low-lying geographical areas where there is a possibility of exposure to sea or brackish water. In these instances, stainless steel must be used because of the corrosion factor.

Closure brackets shall be mounted on the opposite side of the chamber from the duct to avoid crowding the duct and making future hauling difficult.

6.1.2.3 Mounting of closures

Joint closures should be secured in the chamber in such a way that they do not obstruct, or are likely to be affected by, any future installations.

Closures should be mounted vertically on the long side of the chamber and as high as possible up the chamber wall to ensure minimum water penetration if a port seal should fail and to maximise available space within the chamber.

Closure brackets and cable or microduct loops should be mounted on a side of the chamber with no ducts to avoid obstruction of duct line.

The cable MBR must not be compromised.

Under no circumstances shall a cable be hauled through the coils of another.

6.1.3 Cable handling

There shall be one continuous fibre-optical cable without intermediate joints for all cable types, between:

a. a backbone joint and a roadside cabinet which contains ITS fibre interface Ethernet switch
b. a roadside cabinet which contains ITS fibre interface Ethernet switch and another cabinet(s) (eg signal controller cabinet)
c. a cabinet and a roadside asset (ie AWS, VMS etc).

Joints will only be permitted on the backbone cable where:

d. a spur cable connects or is proposed to be connected
e. a long run has reached the maximum drum length possible. (*This shall ideally be located to coincide with point d. above).

6.1.4 Fibre cable installation

Cable-handling methods must consider the specified MBR and maximum tensile loading of the particular optical fibre cable being installed. The maximum tensile load to be applied to standard cables is 2.5kN (not including lead-in cable, aerial cable or subaqueous cable). This is the maximum longitudinal tension that can be placed on the cable without risking damage to the cable.

Cables should be routed from the duct to the joint or to the next duct in such a way that it is clear and not intertwined with other cables.

Cable ends shall be capped with a heat-shrinkable watertight cap until they can be jointed.

6.1.4.1 Cable bend radius

At any time and position during hauling or blowing/jetting, the manufacturer's recommended maximum pulling tension and MBR of the optical fibre cable shall not be exceeded.

The allowable bending radius for the fibre cable is as follows:

Cable status	Bending radius
Cable under no tension	10 x cable's outside diameter
Cable under tension during installation	20 x cable's outside diameter

6.1.4.2 Break-off couplings

Break-off couplings matched with the cable manufacturer's specifications for linear strength shall be used to attach hauling ropes to fibre cables to prevent stretching, which can cause irreparable damage to cables during the hauling process.

Break-off couplings do not apply to ABF systems.

6.1.5 Locating wires

Where non-metallic strength members are incorporated in a cable, a suitable locating wire (trace wire) shall also be hauled and the ends sealed. Locating wires and draw tapes shall be sealed and neatly coiled.

For ABF systems, microduct and multiducts shall have a built-in (pre-installed) locating tracer wire.

6.1.6 Spare cable in pits and chambers

Where there is to be a joint closure installed in a pit, or the possibility of a future joint, then sufficient length of cable or microduct is to be left to allow the cable joint to be lifted into a clear workspace. A minimum of 10m end or 20m coil should be left, and not exceed MBR requirements.

The coil of spare cable or microduct should be placed inside three direct-fixed cable brackets, which are bolted to a chamber wall, and held there with bungy cord. The three brackets should form a tight enough coil that the cable or microduct springs back into them and no weight is placed on the bungy cord. The cable needs to be able to be pulled out of the brackets if necessary, and should not be tied to the brackets. The cable or microduct must not be fastened such that it cannot be pulled back down the duct, in the case of a dig-up or earthquake. The diameter of the coil should not be smaller than 600mm.

Cables should be routed from the duct to the joint in such a way that it is clear and not intertwined with other cables.

A 5m coil of cable should be left in any turning pit.

At each backbone pull pit, 20m of optical fibre backbone cable shall be left neatly coiled.

Where ABF is used, the ducting carrying the microducts shall pass directly through a pull pit.

At each backbone jointing chamber, 20m of optical fibre backbone cable shall be left neatly coiled within the triangulated storage brackets (on the inside, not the outside of the triangle). This shall only be the case for ABF microducts where the ABF is connected to a FIST joint in the jointing chamber.

An elasticised band shall be stretched over the three brackets to hold the cable in place.

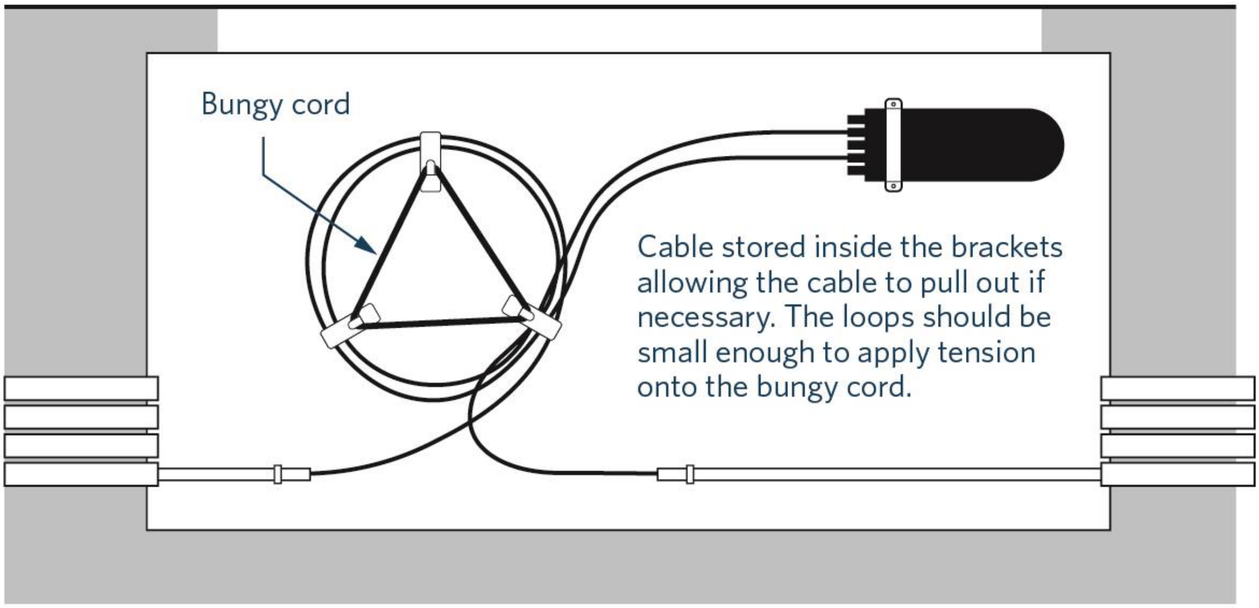

Figure 12. Chamber cable/microduct management.

6.1.7 Tension on cable ties

All cable ties must be tensioned to ensure no movement of fibre, but the tension must not introduce macrobending.

No compression of the cable must occur.

Figure 13. Cable tie is too tight.

6.1.8 Heat shrinking

Cables or microducts entering the ports of the closure should be, after heat shrinking, set straight down from the closure base without any angle or deviation.

The cables/microduct and port must be thoroughly abraded with sandpaper and cleaned with isopropyl alcohol before heat-shrinking the port seal, thus ensuring a leak-free seal (as per manufacturer's instructions for the closure).

Aluminium foil should be used to protect the cable/microduct below the seal from heat during the process of shrinking. This foil should enter no more than 20mm into seal. Small cable overheat protection may be used to pack small cables up to the minimum shrinkage diameter of the seal to be used.

Hot-air guns must be used.

6.1.9 Pressure testing

All closures shall be pressure tested after preparation to ensure that they are sealed properly.

6.1.10 Over-sleeve standards

In the event that the use of an FOSC-type closure has been approved by Waka Kotahi, over-sleeve tubing should extend to within 10mm of the butt of the cable and should not extend beyond 10mm past the cable ties on the tray, such that it encroaches into the path of the fibres.

This should apply to all loose-tube cable installations including OFDFs where the fibre splice tray must be hinged or lifted off to gain access to the trays below.

Foam tape (normally supplied with OFDFs) or rubber tape should be used to protect over-sleeve tubing from being crushed by overtightening of cable ties where they enter splice trays.

6.1.11 Moisture-absorbing bags

Moisture absorbing silica crystal bags must be used in closures, as moisture and water break down splices and cloud the glass, causing significant problems.

Each time a closure is accessed, the moisture bag must be replaced with a dry one.

6.1.12 OFDF and patch cord management

6.1.12.1 OFDF

The following procedure is to be followed regarding OFDF:

- Cable entering optical fibre distribution frames (OFDF) should be mechanically fixed, and strength members should be fixed with an appropriate clamp and/or anchor device.
- Compression glands should be used together with cable ties to ensure there is no way of accidentally pulling the cable from the OFDF.
- Sufficient cable length should be left in the nearest pit to allow for easy opening or removal of OFDF for repairs or additional work.
- Velcro ties should be used on pigtails and patch cords except when securing cords to splicing trays.
- When using cable ties to secure pigtails to trays, wrapping a foam tape or a few wraps of PVC tape under the ties will prevent macrobending of the fibre inside.
- PVC tape is acceptable to use to fix cables as an alternative to Velcro.
- Flexible conduit should be used to protect pigtails and patch cords wherever they are run under floor spaces, along cable trays or cable ladders, or in any area where they could potentially be harmed in any way.

6.1.12.2 Fibre connectors

If not properly maintained, fibre connectors can be a major source of insertion loss and reflections.

Connection and connector quality is critical, as poor jointing or splicing will introduce higher levels of attenuation and can throw out network design parameters. The high optical power of a laser can permanently damage a connector by carbonising microscopic particles of dirt on the connector end face, hence the importance of cleanliness.

The following points should be noted:

- Each time a connector is mated, it must be cleaned and dried.
- Adaptors must be cleaned and dried before attaching a connector.
- Always attach endcaps to unmated connectors or adaptors.
- Do not pull, twist, kink or otherwise stress any optical patch cord or pigtail.
- Do not use index-matching gel on any fibre connections.
- Maintain the MBR of 30mm for 3mm cord.

6.1.12.3 Patch cords

Patch cords should be managed in such a way that they are protected against accidental damage and from weight stress. A form of patch cord management system should be adopted to deliver patch cords to equipment from the OFDF.

Movement of sliding trays should be allowed for and this taken into consideration when running any patch cords, to allow easy opening of the OFDF after commissioning.

Note that the network switch in the roadside cabinet shall be installed in such a way that fibre patch cords are not subjected to excessive bending or crushing when cabinet door is closed as this causes additional attenuation loss.

6.1.13 Cable duct management

For detail regarding duct entry into chambers, please refer to the latest version of ITS design standard: Jointing chambers and pull pits.

6.1.14 Environmental considerations

6.1.14.1 Rubbish disposal

After completion of work, all rubbish and excess materials (ie cable off-cuts, duct tape, blue ribbon, old cable ties, equipment packaging etc) must be removed. This includes the removal of backfill when trenches or chambers are installed. The work site is to be left in a clean and tidy condition.

6.1.14.2 Water disposal

In the event that water needs to be pumped out of a chamber before entry, or water needs to be used in the process of concrete cutting/drilling, local authority rules regarding discharge and removal must be adhered to.

6.1.14.3 Damage to landscaping and structures

Contractors must avoid damage to surrounding landscape or structures when undertaking works on the Waka Kotahi network. Any damage must be rectified as per the local road authority's standards, at the contractor's expense.

The following are a couple of examples to take note of:

- If driving on a site results in ground surface damage by the vehicle, the surface must be repaired.
- If the work requires removal of earth (ie during the installation of a new chamber or trench), the exposed soil must be covered with straw or similar protective layer to minimise contamination of surrounding waterways and drains.

7 DESIGN FOR SECURITY

This section defines the requirements to ensure the intelligent transport system can be secured and maintain integrity.

7.1 Security outcomes

To be defined.

8 APPENDIX A – <TITLE>

9 APPENDIX B – <TITLE>

10 REFERENCES

This section lists all external and Waka Kotahi references included in this document.

10.1 Industry standards

Standard number / name	Source	Licence type and conditions
Health and Safety at Work Act 2015	NZ Legislation website	Public
Recommendation ITU-T G.652.D-2009 Characteristics of a single-mode optical fibre and cable		
AS 60529-2004 Degrees of protection provided by enclosures (IP Code)		
IEC 60794-5-20 Optical fibre cables – Part 5-20: Family specification Outdoor microduct fibre units, microducts and protected microducts for installation by blowing		
EN 50173-1 Fibre attenuation norm		
ISO/IEC 11801 2nd Edition Standard for in-building fibre systems		
EN 50174 Cable installation norm		
EN 50346 Fibre connection measurement standard		

10.2 Waka Kotahi standards, specifications and resources

10.2.1 Standards and specifications

See the Waka Kotahi website for the latest versions of the ITS design standards, delivery specifications and core requirements listed below.

Document name
ITS core standard: General requirements
ITS delivery specification: Roadside cabinets
ITS design standard: Jointing chambers and pull pits

10.2.2 Resources

Document name / code	Waka Kotahi website link

10.3 Drawings

See the Waka Kotahi website for the latest versions of the ITS standard drawings listed below.

Drawing number

11 CONTENT TO BE REDIRECTED

This section records any circumstances where content from this document will be reclassified and moved into future documents. This table is then updated with a reference to the new location.

Section reference	Section name	Future document	Class
4.3.1.1	Cabinets	Roadside cabinets delivery specification	011 Enclosures
4.3.1.1.1	Fibre jointing cabinet	Roadside cabinets delivery specification	011 Enclosures
4.3.2	Cable protection	Ducts design standard	010 Civil infrastructure
4.7.2	Labelling of cables	Asset naming convention core standard	000 Core requirements
4.7.3	Labelling of closure domes	Asset naming convention core standard	000 Core requirements
5.6	Contractor responsibilities	Health and safety core standard	000 Core requirements
5.7	General work site hazards	Health and safety core standard	000 Core requirements
5.8	Eye safety and viewing of fibres	Health and safety core standard	000 Core requirements
5.9	Disposal of fibre	Health and safety core standard	000 Core requirements
5.10	Solvent use and disposal	Health and safety core standard	000 Core requirements
5.11	Working at height	Health and safety core standard	000 Core requirements
5.12	Working in confined spaces	Health and safety core standard	000 Core requirements
5.13	Gas testing	Health and safety core standard	000 Core requirements
6.1.14	Environmental considerations	Environmental core standard	000 Core requirements
6.1.14.1	Rubbish disposal	Environmental core standard	000 Core requirements
6.1.14.2	Water disposal	Environmental core standard	000 Core requirements
6.1.14.3	Damage to landscaping and structures	Environmental core standard	000 Core requirements