DUCTS

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

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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
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		Technical Specialist (Technology Operations)	Waka Kotahi
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		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	20/09/10	Tom Harris	Senior Design Engineer, WSP Opus	ITS draft specifications issue
0.2	25/01/11	Tom Harris	Senior Design Engineer, WSP Opus	AMA specifications review Draft R1
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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RETIRED	The document is obsolete, and/or superseded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
AS/NZS	Australian/New Zealand standard
AWS	Advanced warning sign
BEP	Best environmental practice
DAS	Distributed acoustic sensing
DN	Diameter nominal
EN	European standard
EPR	Earth potential rise
FIST	Fibre infrastructure system technology
HD	Heavy duty
HDPE	High-density polyethylene
HSE	Health and Safety in Employment [Act and/or Regulations]
ID	Inside diameter
IEC	International Electrotechnical Commission
MD	Medium duty
NB	Nominal bore
OD	Outside diameter
PE	Polyethylene
PIPA	Plastics Industry Pipe Association of NZ
POP	PIPA polyolefin technical guidelines
RFID	Radio-frequency identification
SDR	Standard dimension ratio
SN	Nominal stiffness
UV	Ultraviolet

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

To be defined.

3.2.1 System definition

Ducting is a critical part of the backbone infrastructure required to enable the delivery of ITS equipment to the roadside. Ducting enables the provision of utilities, such as communication and power to support the deployment of ITS equipment. An additional consideration for ducting configuration is to optimise installation in order to support deployment of fibre optic detection systems.

3.2.2 System class

010 Civil infrastructure.

3.3 Scope

The purpose of this document is to specify the requirements for ITS power and communications ducting design, supply and installation.

This design standard sets out the requirements for the design and construction of the ITS communications infrastructure main ducts and the local power, fibre-optic and control cable and feeder cable ducts. It is laid-out in two sections: conventional ducting and air-blown fibre (ABF) ducting.

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 System architecture

The layout of an ITS duct route along a state highway and its connections is dependent on several considerations:

- whether the ducting network is in an urban, or rural environment
- whether there are power, detector or communications cables
- the type of fibre required
- the type and density of assets along the route.

4.2 Route selection

When planning the route for a fibre cable, the following shall be applied:

- Check for any future roadworks that may affect the offset selected.
- Ensure the required separation from other underground plant is maintained.
- Lay cable in straight lines with minimal depth variances or undulations as practical, as this will reduce both recording costs and maintenance costs and reduces the risk of accidental damage by other contractors.
- Avoid areas contaminated by effluent, chemical wastes or leakage of dangerous fluids, petrol etc or areas that are likely to be inundated by water.
- Note areas of earth potential rise (EPR) and design duct networks passing through them so no joints in the cable are required in the EPR zone.
- Ensure safe and easy access for workers and/or vehicles, where possible.
- When new cables are to be laid, the future excavation of swale drains over the cable route must be given consideration.
- Consider whether the cable will be required to perform a distributed acoustic sensing (DAS) role.

4.3 Shared trench line and chambers

It is important to note the following when identifying Waka Kotahi cable:

- Both Waka Kotahi and Vodafone share the same trench line and chambers for their respective telecommunication networks in Auckland on much of state highway 1 (SH1) and state highway 16 (SH16). However, each entity uses its own specifically coloured duct. The size and colour of the commercial operator’s duct may vary. Waka Kotahi cables are not permitted to be drawn through them and vice versa.
- Often a Waka Kotahi chamber or a chamber containing Waka Kotahi fibre could have a cover set branded with the Telstra or Saturn logo (forerunners to Vodafone).
- Waka Kotahi and Vodafone joint closures are generally not housed in the same chamber, although there are cases where they are. These are generally located in 1200mm square double-lid chambers.

4.4 Fibre route diversity

Ideally, a fibre circuit should have full diverse path protection and automatic switching failover to a backup circuit in the event of a cable being cut or damaged. However, this is not always available for cost and/or geographical reasons.

Partial diversity can be made available by means of a second cable being run in a different duct along the same route. The chances of a complete outage are reduced as both cables/duct and sub-ducts must be damaged at the same time. Even if this path has no automatic switching, the outage time is reduced considerably against the time spent repairing a damaged cable.

Full diversity can be achieved by working with third parties or having a fibre cable installed in a separate route. For example, fibres can be shared with dark pairs connected to other networks, such as KiwiRail, in case of fibre or duct line severance.

4.5 Conventional ducting

4.5.1 Definition

The term conventional ducting refers to polyvinyl chloride unplasticised (PVC-U) and polyethylene (PE) ducting, which is supplied in individual lengths or in coils. The ducts will typically have a nominal diameter of 100mm and may be sub-ducted but may come in other sizes for different applications. The ducts will be used for ITS purposes, so will be conveying fibre-optic cables, low-voltage and extra-low voltage power cables, and detector cables.

Conventional ducting typically terminates when it enters a jointing chamber, pull pit or local access chamber and the fibre, power cable or detector cable housed within is drawn from duct to duct within the chamber.

4.5.2 Physical layout

Ducting provided for Waka Kotahi ITS purposes shall remain within Waka Kotahi designation wherever practicable.

Individual duct routes shall be joined at jointing chambers, where a cable joint exists, or at pull pits, where no cable joint exists.

The duct access points shall be located outside swales or drainage paths and wherever possible, shall be accessible without the requirement for temporary traffic management. For further information, see the latest version of ITS design standard: Jointing chambers and pull pits.

There may be contention on the transverse placement of a duct and its access chambers if the duct is to contain a fibre core that will be dedicated to DAS. A DAS fibre is required to be close to the carriageway in order to detect passing traffic. Therefore, it may be desirable or necessary to install a separate DAS cable route.

Equipment cabinets shall be connected to a spur duct at a suitably located jointing chamber which contains the 12f fibre and any other power/detector cables, as necessary. The jointing chamber shall house the fibre infrastructure system technology (FIST) enclosure.

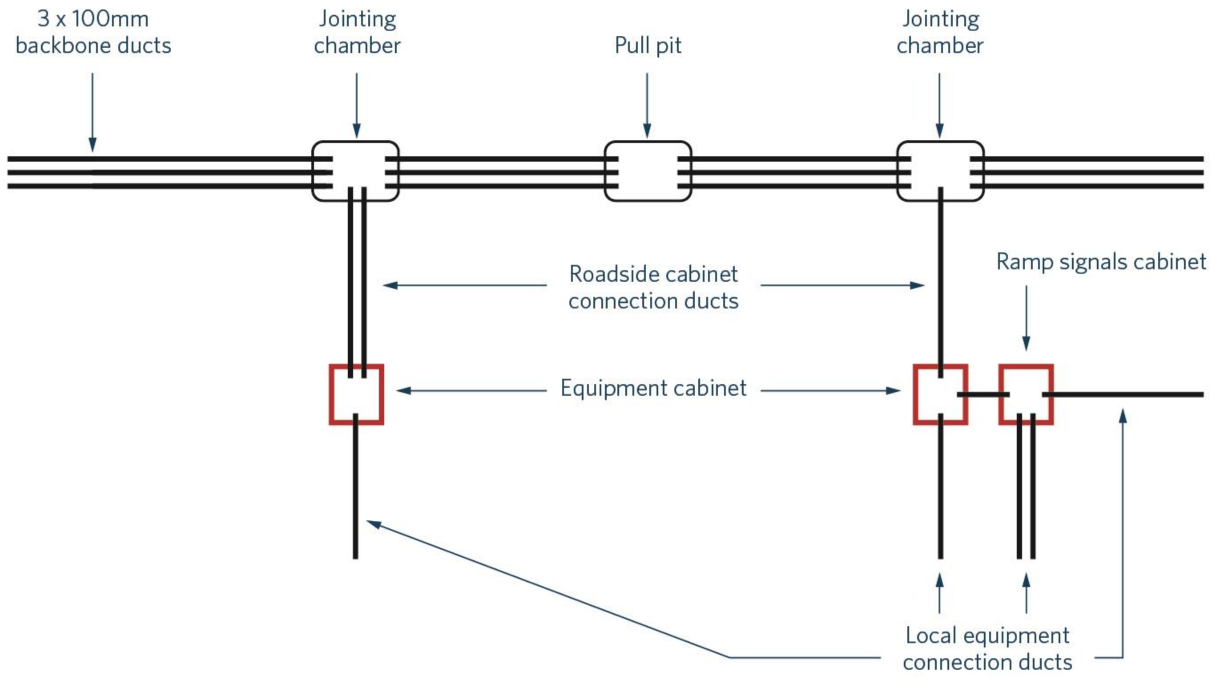


Figure 1. Typical duct configuration.

- Only the ducts themselves are shown.
- Each equipment cabinet has its own fibre joint in a jointing chamber on the backbone route. The 12f fibre spur is routed down a roadside cabinet connection duct to the equipment cabinet where the fibre splice tray and network switch are located.
- In order to add a new mid-block site, a new jointing chamber, roadside cabinet connection duct, cabinet, fibre joint, splicing tray and network switch will be required.

4.5.3 Cable ducts

4.5.3.1 Type

Ducts shall comply with AS/NZS 61386:2015 or AS/NZS 2053.2:2001 Conduits and fittings for electrical installations – Rigid plain conduits and fittings of insulating material. Ducts manufactured to these standards must be independently certified and licenced.

Rigid (PVC-U) ducting is supplied in lengths (known as ‘sticks’) and may only be used in trenches. PVC-U ducting is to be independently BEP (best environmental practice) certified.

PE ducting (known as continuous ducting), usually supplied in coils, shall be used for thrusted or directionally drilled applications mainly, but may also be used in trenches.

Flexible ducting is not permitted for use in Waka Kotahi ducting systems.

4.5.3.2 Duty rating option 1

AS/NZS 61386.21:2015, table 207 rates the duty rating of the pipe to an equivalent ring stiffness:

- Medium duty (MD) (ring stiffness SN 4) rated duct shall be used for salmon ducting.
- Heavy duty (HD) (ring stiffness SN 10) rated duct shall be used for orange ducting.
- Very heavy duty (ring stiffness SN 25) may be used where deemed appropriate.

If MD is used for orange ducting, additional mechanical protection (such as a cable cover) shall be installed above the duct, in line with AS/NZS 3000:2018 Australian/NZ Wiring Rules, section 3.11 Underground wiring systems.

4.5.3.3 Duty rating option 2

AS/NZS 2053.2, table 101 specifies duty rating by wall thickness:

- Light duty (ring stiffness SN 4) rated duct shall be used for salmon ducting.
- MD (ring stiffness between SN 10 and SN 25) rated duct shall be used for orange ducting.
- Heavier duties than specified may be used.

4.5.3.4 Colour

Orange shall be used for power cables.

Salmon shall be used for fibre-optic cables.

Detector feeder cables may be located in either orange or salmon ducting.

4.5.3.5 Print on duct

The backbone duct shall have the following print marking:

- manufacturer’s name
- nominal size
- ‘ELECTRICAL’ for orange duct or ‘COMMS’ for salmon duct
- manufacturing standards AS/NZS 61386 or AS/NZS 2053
- duty rating: ‘MD’ or ‘HD’
- ‘NZTA’
- date of manufacture
- ‘BEP certified’
- license number from independent certification agency
- batch number.

Note: For print marking on duct, length of unmarked pipe shall not exceed 1m.

When installed, the print shall be face up.

Note: Sub-ducts inside backbone duct do not require ‘NZTA’ print.

4.5.3.6 Cover

In general, duct installation may be either directionally drilled, thrusted or laid in open cut trench. Where crossings of existing roads or the like is required, directional drilling or thrusting of duct shall be used as the preferred means to install ducts.

Minimum cover to ducts shall be as required for the duct situation as detailed in the latest version of ITS standard drawing 000-0000-0-7104-02-RX:

- 1m when alongside the carriageway (in the berm)
- 2m when crossing under a motorway carriageway
- 1.5m when crossing under a non-motorway carriageway.

4.5.3.7 Alignment

Duct routes shall be kept as straight as possible.

For PE duct, the minimum radius permitted is 25 x nominal radius (AS/NZS 2033:2008). If a greater radius is dictated by the duct manufacturer or by the cable being hauled, the greater value shall be used.

Pipe standard dimension ratio (SDR)	Minimum bending radius of curvature
SDR 17	25 x DN

Table 1. Minimum bending radius of PE pipe based on published recommendations of the PE100+ Association.

SDR is a method of rating the dimensions of PE pressure piping. SDR is a ratio of pipe diameter to wall thickness and can be expressed as SDR = D/s. SDR 11 means that 'D' outside diameter of the pipe is eleven times the thickness 's' of the wall.

Example: The minimum radius of a bend for placing a 110mm SDR 17 pipe is 110mm x 25 = 2.75m.

Note: It is not recommended to bend any PE pipe to a radius of curvature less than 25 x the outside diameter (OD) of the pipe.

Where gradual curves are required in a duct system, the natural flexibility of a duct could be used to form the curve if it fits within the manufacturer's recommendations. The radii of the curves for 100mm diameter PVC-U duct shall not be less than 35m.

Where bends greater than 25 x OD for PE duct are required, a pull pit or chamber shall be installed.

Where bends in excess of 30 degrees (where preformed sections will be used) for PVC duct are required, a pull pit or chamber shall be installed. Multiple bends between chambers, or even a single bend on a long run between chambers, can make cable pulling difficult. In such a case, the designer must be satisfied that the stiffest or heaviest cable likely to be installed can be safely pulled or blown through.

Duct systems shall be designed with frequent pulling pits where the direction of the system requires changes. Bends in ducts create friction when installing cables. Multiple bends or a long cable pull can create heavy resistance and increase friction. Under no circumstances shall a cable be pulled with a tension greater than the cable manufacturer's recommended values, as this can lead to damage of the internal cores of the cable.

4.6 ABF ducting

4.6.1 Definition

ABF ducting refers to a duct containing a single tube, or multiple tubes designed specifically for blowing fibre cables through. This method of ducting is not suitable for the conveyance of power or detector cables. In such circumstances, conventional ducting may be laid alongside the ABF duct.

Duct diameters will vary depending on the number of tubes and the degree of protection or armouring provided. For example, a typical nine-way duct would be expected to have a diameter of around 40mm and a typical armoured six-way duct will be of a similar size. The internal diameters (ID) of the microducts within these ducts will be 10mm and 3.5mm.

ABF ducting is designed to provide a continuous point-to-point air and watertight pathway between fibre joints or cabinets through which a fibre cable is blown. The individual tubes within the duct are connected with purpose-made connectors and the tube connection locations are housed in purpose-made splice enclosures. No open-ended ducts or their tubes are permitted anywhere on an ABF network, so all ends must be sealed with suitable purpose-made plugs, eg end caps and divisible seals or gas blocks.

4.6.1.1 Nomenclature

The term multiduct refers to the overall duct.

The term microduct refers to the individual tubes (small ducts) housed within the multiduct.

4.6.2 Physical layout

Ducting provided for Waka Kotahi ITS purposes shall remain within Waka Kotahi designation wherever practicable.

Individual duct routes shall be joined with enclosures specifically designed for that purpose. These enclosures may be directly buried where a fibre-only ABF duct network exists, or they may be housed within a jointing chamber where an ABF fibre is to be jointed onto a fibre cable designed for conventional ducting. In this case, the enclosure shall be submersion rated (IP68).

There are two alternative system architectures.

4.6.2.1 Conventional layout

Where the backbone fibre route shares a trench with a conventional duct and chambers, the system may be configured in a similar way as used for conventional ducting whereby the ABF mini duct enters the chamber and the microducts within enter the FIST joint. This method carries some risk, as handling the joint can lead to cable pull within the microducts unless the cable is securely locked in place. The FIST may be secured in a swing frame at the top of the chamber, allowing it to be swung to a vertical position for maintenance access. This would require the maintainer to work on the fibres in situ but would reduce the risk of fibre damage.

4.6.2.2 Chamberless layout

The backbone route can share a trench with conventional ducting but remain isolated from it by passing directly through or around the chambers. This permits the use of local duct access chambers on the conventional portion of the duct network, as the larger jointing chambers and pull pits would not be required (their size is required for fibre coiling and access). This type of fibre network is therefore chamberless.

Local ducts and chambers for power supplies and detection will be independent of the fibre.

The necessary 12mm OD/10mm ID microducts (such as those carrying the 96f/48f backbone) and 5mm OD/3.5mm ID microducts (for 12f/6f fibre cables) shall be broken out from the backbone multiduct and connected to the spur ducts with suitable IP68-rated connectors and enclosed within suitable enclosures – called an H-branch enclosure, or a tube distribution closure, as appropriate. The spur ducts will then be routed into an above-ground fibre splicing cabinet. This arrangement permits the unused microducts to remain unbroken. As an alternative, the backbone duct itself may be taken into the base of the jointing cabinet without the need for connectors or enclosures.

A radio-frequency identification (RFID) tag may be placed above the enclosure once it is buried in order to permit relocation at a later date.

The fibre jointing (splicing) cabinet will be located close to the equipment cabinet and connected to it via a suitable duct that is designed to carry the necessary number of fibre cables, plus a power cable to run any electrical fans or dehumidification equipment inside the fibre jointing cabinet that may be required (passive jointing cabinets are preferred).

The 12f/6f spur will run from the fibre splicing cabinet to the communications cabinet and will terminate in the fibre tray, then into the network switch in the usual manner.

4.6.2.3 Adding additional cabinets onto the route

When designing a chamberless ABF duct network, some advance planning can save later rework. If a full suite of assets is not provided from the outset, their future locations, or at least an awareness of future assets, will allow the designer to connect the necessary microducts at jointing cabinets and buried enclosures in order to avoid digging them up and re-opening them.

Installation of additional equipment cabinets between sites where a fibre splicing cabinet exists can be connected in the following ways:

- At the new site, a new H-branch enclosure or tube distribution closure (as appropriate) will be installed on the main duct line at the desired location. The appropriate 5mm OD/3.5mm ID microduct would then be spliced out to the new equipment cabinet.
- At the original site, the same 5mm OD/3.5mm ID microduct will be connected to an extension section from the end of the microduct in the fibre jointing cabinet to the adjacent equipment cabinet.
- A 12f/6f fibre will then be blown through the microduct between the new equipment cabinet and the original equipment cabinet.
- The fibre shall then be connected between media converters (or similar apparatus as necessary) located in the new and original equipment cabinets. The signal from the equipment in the new cabinet will therefore be connected to the network switch in the original equipment cabinet.

The resultant network results in fewer joints on the backbone route and fewer network switches, which will therefore be cheaper to install and renew.

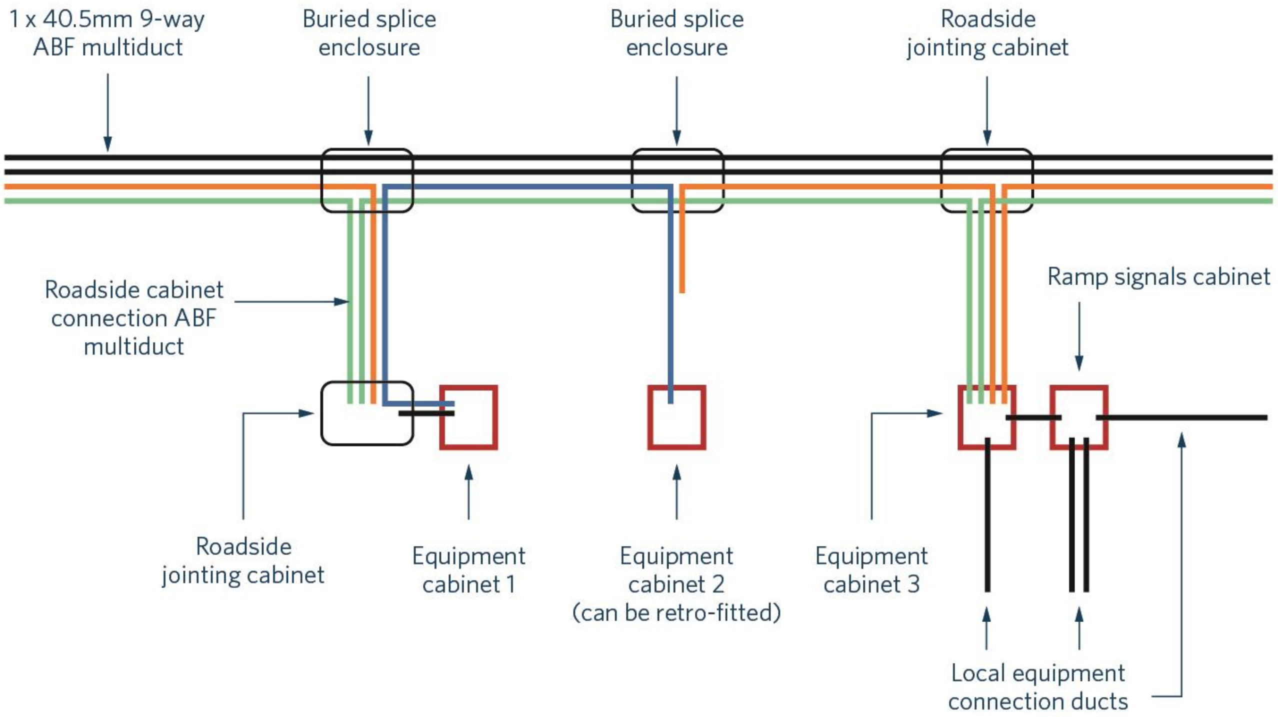


Figure 2. Typical ABF-ducted ITS layout

For clarity, only a sample of the individual microducts are shown, and the fibre splice tray and network switch located in the equipment cabinets are not shown.

The primary difference with a conventional duct layout is that the microducts replicate the route the fibres take or are planned to take.

Each existing equipment cabinet is shown with its own fibre joint in a jointing cabinet, either on the mainline of the backbone or on a spur. The jointing cabinet on the right could also be constructed as a chambered joint if necessary.

The green line in the diagram represents the 12mm OD/10mm ID microduct connections through which the 96f/48f backbone fibre will be blown.

The orange line in the diagram represents the 5mm OD/3.5mm ID microduct connections through which the 6f or 12f spur fibre, or the 2f DAS fibre can be blown.

The yellow cabinet (equipment cabinet 2) is a site which will have been added after the network was installed. It is shown connected directly to equipment cabinet 1 by the blue line, one of the spare 5/3.5mm microducts, which permits the equipment in cabinet 2 to operate from the network switch housed in cabinet 1. The blue microduct passes through the jointing cabinet with no breaks, which permits the fibre to be blown directly between media converters, housed in cabinets 1 and 2.

4.7 Ramp signals

Where ramp signals are provided, the multimode fibres from the ramp signals cabinet to the advanced warning sign (AWS) may run through a conventionally ducted backbone network, if it is convenient to do so. However, cables for ramp signalling equipment will not be permitted to run through ABF ducting. Where an ABF backbone is provided, the ramp signal duct network shall utilise conventional ducting and be provided separately. See section 4.8.1.3.1 ITS equipment connection ducts in this document for ducting requirements, and the latest version of ITS design standard: Ramp meter systems.

4.8 Installation

4.8.1 Conventional ducting

4.8.1.1 ITS backbone ducts

4.8.1.1.1 General

In general, the ITS backbone ducts shall be in the highway berm parallel to the edge of the carriageway and ramp shoulders and outside any side protection barriers.

Chamber locations shall be as specified in the latest version of ITS design standard: Jointing chambers and pull pits, section 4.1 Chamber locations.

4.8.1.1.2 Urban ducting

ITS backbone ducts shall be installed along the highway connecting to existing jointing chambers at each end.

The ITS backbone shall have two 100mm nominal bore (NB) MD ducts coloured salmon and one 100mm NB HD duct coloured orange. One of the salmon ducts shall contain four 32mm sub-ducts.

4.8.1.1.3 Rural ducting

When ducts are installed for regional rural highways, depending on future need the ITS backbone duct shall reflect the asset density required, proposed or projected along the highway.

If power for roadside assets is sourced locally and there is a low density of loop detectors, the backbone ducting may consist of two ducts, or one duct.

A two-duct backbone shall comprise one 100mm NB orange HD duct and one 100mm NB salmon HD duct containing four 32mm OD PE sub-ducts arranged as follows:

- three sub-ducts coloured salmon for fibre-optic cable
- one sub-duct coloured orange for low-voltage power cable.

A one-duct backbone shall comprise one 100mm NB orange HD duct (as it may contain power and fibre together) containing four 32mm OD PE sub-ducts arranged as follows:

- three sub-ducts coloured salmon for fibre-optic cable; and
- one sub-duct coloured orange for low-voltage power cable.

4.8.1.1.4 Sub-ducts

Four 32mm NB sub-ducts shall be installed in one of the salmon backbone fibre-optic cable ducts.

Sub-ducts shall:

- be PE duct, installed in one continuous length from jointing chamber to jointing chamber or from jointing chamber to pull pit

- protrude into jointing chambers and pull pits by 400mm–600mm to allow for connection of hauling equipment and to provide for a smooth radius when installing cables.

4.8.1.2 ITS roadside cabinet connection ducts

4.8.1.2.1 Jointing chamber connection ducts

Local duct connections from the ITS backbone jointing chambers to roadside control cabinets shall have:

- one 100mm NB MD duct coloured salmon
- one 100mm NB HD duct coloured orange
- separate ducts for local power and control cable ducts as required for connections to the ITS systems equipment
- any telephone cable ducts shall be 50mm NB duct coloured green.

Duct connections into jointing chambers shall be made with straight ducts aligned directly to the roadside control cabinet.

4.8.1.3 Local equipment connection ducts

4.8.1.3.1 ITS equipment connection ducts

Local duct connections from the roadside control cabinets shall have separate ducts for power and data/control cables.

Duct connections into the roadside control cabinets and into ITS equipment supports or foundations shall be made with long radius bends, a minimum bending radius of 600mm is required for one 100mm duct (a factor of 6).

Local equipment connection ducting shall be installed to connect assets with their control cabinets, such as between a communications cabinet and a CCTV camera or VMS, or between a ramp signals controller cabinet and the lanterns, detectors and AWS. The ramp signals ducts shall have:

- one 100mm NB MD duct coloured salmon running the entire length of the on-ramp for local fibre and inductive loop feeder cable
- one 100mm NB HD duct coloured orange running the entire length of the on-ramp for power cable.

Chamber locations shall be as specified in the latest version of ITS design standard: Jointing chambers and pull pits, section 4.1 Chamber locations.

4.8.1.3.2 Cable pits and jointing (colloquially known as toby) boxes

The supply and installation of cable pits and the connection of ducts shall comply with the latest version of ITS design standard: Jointing chambers and pull pits.

4.8.1.4 DAS ducts

4.8.1.4.1 Introduction

DAS is a method that can be used to locate moving vehicles along a transport corridor (road or rail) from vibrations that vehicles transmit through the ground to a buried fibre-optic cable. The fibre can be either an existing cable, or one installed specifically for the purpose.

This section deals with a duct installed along a carriageway specifically for DAS purposes.

The designer must be satisfied that the DAS fibre route is:

- located in a position where it will receive the best possible signal from passing traffic
- provides close coupling between the ground and the fibre in order that the fibre can detect as much traffic noise as possible.

A fibre along a road can be laid in one of two locations:

- Alongside the carriageway, on one or both sides, as close to the edge of the carriageway as practicable. This method is the most likely to be adopted where there is an existing backbone fibre route. Alternatives to this arrangement may include a DAS-only duct on one or both sides of a road, DAS-only and DAS/backbone ducts on either side of a road, or a DAS-only duct to bypass sections of backbone duct where the DAS is part of the backbone fibre cable where the main backbone deviates from the edge of the carriageway to a location where a signal is difficult to receive.
- Along the central median. This method may be used for lightly/moderately used carriageways of a motorway or expressway. It can be used as a bypass section where a DAS/backbone fibre deviates from the edge of the carriageway to a location where a signal is difficult to receive, or as a complete route in its own right. It provides equal signatures from both carriageways. A wide central median is not a suitable location as signal reception may not be achievable from both carriageways.

For motorways and expressways with two lanes in each direction, a fibre located in the median provides the best signal from both carriageways. The quality of this signal will deteriorate with a wider median, or wider carriageways. In situations where there is a lot of traffic, the carriageways are very wide or the carriageways are further apart, the best solution would be to install a fibre along either side of the road.

4.8.1.4.2 Duct type

The duct shall comply with AS/NZS 61386:2015. Duct manufactured to this standard must be independently certified and licenced.

Heavy-duty PE ducting is a minimum requirement.

4.8.1.4.3 Duct size

For a DAS-specific cable, a small diameter duct is needed. It is suggested that a duct of 25mm ID or OD is installed.

4.8.1.4.4 Duct depth

Not every method of installation uses ducts, but the optimum depth for burying the fibre is dependent on the burial method:

- slot cut: 0.1m to 0.3m
- direct bury: 0.3m to 0.5m
- ducted: 0.3m to 0.5m.

4.8.1.4.5 Duct offset

Generally, the further the fibre is located from the noise source the smaller the signal received. The main factor to consider when placing the fibre is physical distance from the lane(s) that need to be monitored.

The detection equipment requires a certain amount of signal to work effectively. If the fibre is offset greater than the manufacturer's recommendations, there is likely to be reduced system performance due to fewer detected vehicles being tracked.

Burial method	Offset from lane	Performance
Slot cut	<10m	Very good
	10m - 14m	Good
	14m - 17m	Average
Direct buried	<9m	Very good
	9m - 13m	Good
	13m - 16m	Average
Ducted	<8m	Very good
	8m - 12m	Good
	12m - 15m	Average

Figure 3. Recommended fibre offset for the various deployment methods.

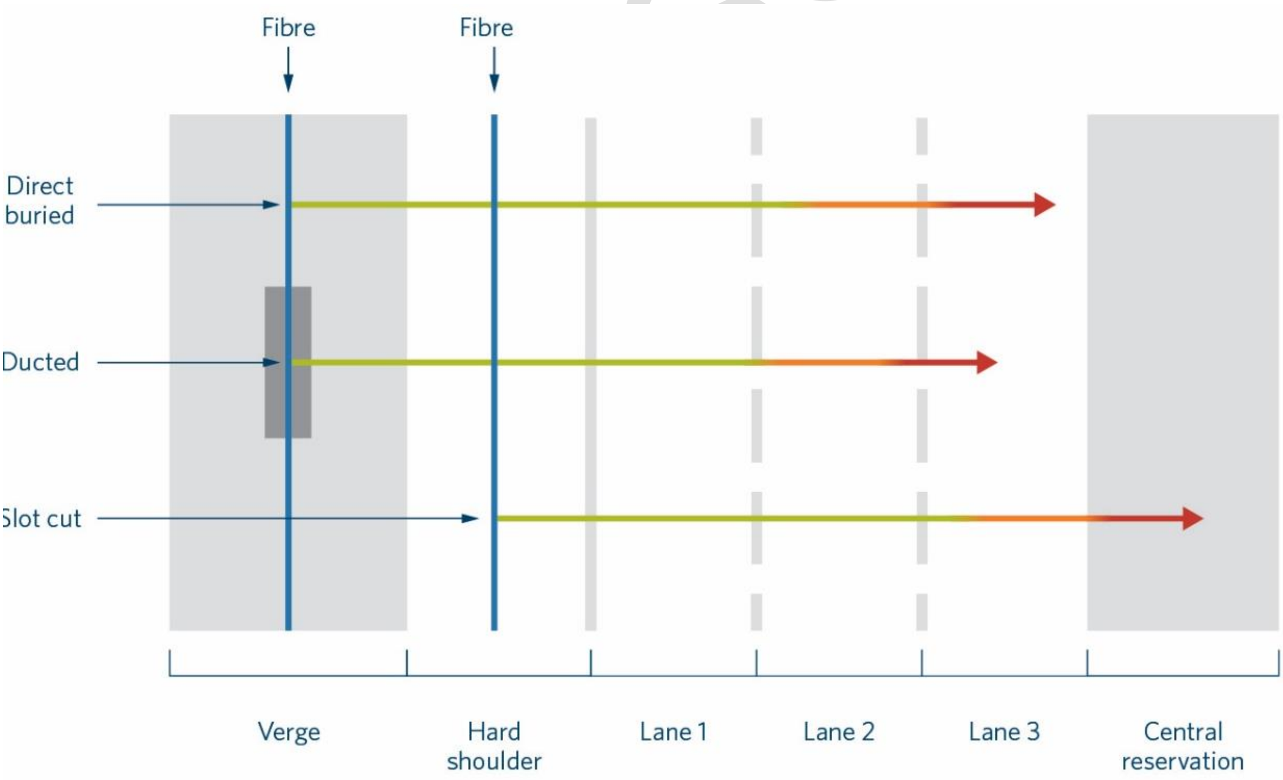


Figure 4. Fibre offset and burial type against DAS system performance. The colours of the arrows relate to the Performance column in Figure 3. above. This image is used for representation purposes only.

4.8.1.4.6 Installation technique

The duct can be installed by any means suitable for the location it is to be laid, including thrusting, trenching, micro trenching, chain digging or mole ploughing.

A suitably robust duct shall be used that will not become damaged by the passage of maintenance or wayward vehicles.

A superior signal will be received by the detection equipment if the DAS fibre has:

- close coupling to the ground, such as slot cut or direct bury
- is installed in firm ground conditions; the firmer the better.

However, for cable installation following capital projects, replacement or maintenance purposes, a ducted solution would be more convenient. The firmness of the ground around the duct will therefore be a factor in the signal strength obtained from the fibre.

The duct shall not be cast into a concrete barrier or in contact with the foundations of any barrier type due to the risk of transmitting vibration from within the barrier.

The median duct shall be connected to the roadside backbone fibre with the use of crossroad structures (under or over) or by thrusting a duct beneath the carriageway.

4.8.1.4.7 Chambers

Provision of chambers along a DAS route will be determined by the length of duct through which the fibre can be hauled or blown.

Full-size fibre chambers are not required, as coils of spare fibre are not required at pulling/fleeting points. It is suggested that chambers will be provided at changes of direction, entry/exit points to structures such as bridges and at locations where an in-line joint is being provided. Otherwise, chambers may be provided at intervals up to 2km and may take the form shown in the latest version of ITS standard drawing 000-0000-0-7104-09-RX.

4.8.1.5 Above-ground ducts

4.8.1.5.1 Concrete-encased ducts

Where it is impractical to install ducts in trenches with the minimum cover requirements, the ducts shall be encased in concrete.

Where the duct is above ground, the concrete cover to the ducts shall be a minimum of 50mm of concrete below and on each side of the ducts and a minimum of 100mm on top of the ducts.

Concrete for encasing the ducts shall be a minimum of 17.5 MPa compressive strength concrete.

Mark all such lengths of encased duct at intervals of approximately 25m with the legend 'ITS Cables' clearly imprinted a depth of 5mm in the concrete during finishing.

The concrete surface shall be trowel or float finished to provide a smooth surface.

4.8.1.5.2 Galvanised steel conduit

Where ducts are exposed above ground and not encased in concrete, galvanised steel pipe conduit securely fixed in place with non-corroding, vibration resistant and ultraviolet (UV)-stable fixings shall be used. The design of above-ground ducting shall consider the ability to pull cables around bends and deviations in the duct (eg at bridges). Access plates for cable pulling or jointing boxes shall be provided where necessary.

The size and numbers of galvanised steel conduits shall match the size and numbers of ducts provided for underground ducting.

All bends in the galvanised steel conduit shall be sweep bends with a minimum radius, which will be a function of the diameter of the tube and elongation required.

Bending radius = 0.5 x diameter of the tube / % elongation required. The % elongation =

- 42% for AKDQ steel
- 60% for annealed 304 stainless steel
- 33% for annealed 409 stainless steel.

Screw joints shall be fitted at 90-degree bends so the bend section can be removed for cable installation.

Galvanised ducting shall be earthed when passing close to power transmission lines or within 2m of railway overhead line electrification equipment.

The galvanised steel conduit shall be fixed with galvanised steel saddles at regular intervals of not more than 2m to the adjacent supporting structure.

All galvanised steel conduit shall be proved and have trace wire and draw tape installed.

Figure 5. Typical galvanised steel ducting on the side of a bridge.

Galvanised steel conduit shall not be attached to safety rails or rail posts or interfere with their performance in the event of a crash.

4.8.1.6 Storage and handling

PE duct

Handling and storage must be carried out in line with AS/NZS 2033:2088 Installation of PE pipe systems and AS/NZS 2566.2:2002 Buried flexible pipelines – Installation.

PVC-U duct

Handling and storage must be carried out in line with AS/NZS 2032:2006 Installation of PVC pipe systems and AS/NZS 2566.2:2002 Buried flexible pipelines – Installation.

4.8.1.7 Trenching

4.8.1.7.1 Excavation

All excavations for trenches shall be to the lines shown on the drawings and to such directions as may be given by the engineer.

The excavations shall be open trenches unless the written permission of the engineer is obtained for other construction methodology.

Not more than 100m of trench shall remain open at one time unless otherwise approved by the engineer.

In excavating trenches, any surfacing materials shall be salvaged and stockpiled as far as possible so as to be replaced after the trench has been backfilled. Any surfacing materials lost shall be reinstated by the contractor at his own expense.

All spoil from the trench shall be kept away from the edge of the trench at the top to avoid overloading the trench sides and to comply with the Health and Safety in Employment (HSE) Act and HSE Regulations.

4.8.1.7.2 Surface cutting

The edge boundaries of trenches and excavations shall be marked on the surface in a line type or colour that is different from markings for existing services.

In sealed areas the sealed surface shall be neatly saw cut, set back from the edge of the excavation. The setback shall be 150mm for a trench width of 30mm or less, and 300mm elsewhere. In unsealed areas the edge of the surface opening shall be kept as neat as possible.

Where the surface consists of cobblestones or pavers, these shall be carefully removed and stored for reinstatement. Any damaged paver units shall be replaced by the contractor.

Should the sides of the excavation slump or the surface surrounding the edge of the excavation become depressed, then the cut shall be opened wider until a stable sub-surface is found. This additional excavation shall be at the contractor's cost.

4.8.1.7.3 Dewatering trenches

The contractor shall maintain all trench bottoms free from flowing or accumulated water, so that all ducts can be bedded, laid and jointed in dry working conditions.

The contractor shall provide sufficient labour and plant, and maintain all drains, pipes, pumps and sumps to keep the works clear of water to the satisfaction of the engineer.

All water shall be disposed of to the approval of the engineer and any damage caused shall be made good by the contractor at its own expense.

4.8.1.7.4 Support of trenches

All work involving excavations must comply with the requirements in the HSE Act and HSE Regulations.

Excavations shallower than 1.5m
Shall not necessarily be regarded as safe from the risk of collapse. The contractor shall consider such excavations on a case-by-case basis and determine if special precautions or work methods are necessary.

Excavations deeper than 1.5m
Excavations equal to or greater than 1.5m are particularly hazardous and must be supported or benched back to a safe slope, as determined by the contractor, in accordance with HSE Regulations.

4.8.1.7.5 Duct installation in trenches

PE duct
Should be installed in line with:

- AS/NZS 2033:2008 Installation of polyethylene pipe systems (AS/NZS 2033)
- AS/NZS 2566.2:2002 Buried flexible pipelines – Installation (AS/NZS 2566.2).

PVC-U duct
Should be installed in line with:

- AS/NZS 2032:2006 Installation of PVC pipe systems (AS/NZS 2032)
- AS/NZS 2566.2.

Where multiple ducts are installed in a trench, suitable plastic spacers shall be used to keep the ducts the correct distance apart.

4.8.1.7.6 Jointing ducts

PE duct
All electrofusion jointing shall be done according to:

- PIPA Technical guideline POP001:2019 Electrofusion Jointing of PE Pipe and Fittings for Pressure Applications (POP001:2019).
- AS/NZS 2033

All butt welding shall be done according to:

- PIPA Technical guideline POP003:2011 Butt Fusion Jointing of PE Pipes and Fittings – Recommended Parameters (POP003:2011).
- AS/NZS 2033

All compression fittings for PE duct should be installed in line with AS/NZS 2033.

PVC-U duct
All solvent jointing shall be done in accordance with AS/NZS 2032.

4.8.1.7.7 Protection of ducts

Marker (warning) tape to AS/NZS 2648.1:1995 Underground marking tape – Non-detectable tape is required by AS/NZS 3000:2018 Australian/NZ Wiring Rules, section 3.11 Underground wiring systems. It shall be installed above all trench-laid ducting containing underground wiring. The tape shall be installed at 50 per cent of the depth of the duct. Thrusted or bored PE duct is exempt from the marker tape requirement.

Where MD duct (per AS/NZS 2053.2:2001, table 101) or HD duct (per AS/NZS 61386.21:2015, table 207) is laid in a trench, a cable cover shall be installed above the duct and the marker tape shall be installed above the cable cover.

The cable cover shall be centrally positioned above the duct and shall be twice the width (diameter) of the duct it is protecting.

4.8.1.7.8 Backfilling of trenches

Ducts in trenches shall be backfilled over as soon as is practicable after they have been laid, bedded and jointed as specified.

Excavated materials shall only be used for backfilling where the excavation to be backfilled is in a grassed or planted berm.

In sealed or unsealed roadways, driveways or footpaths, hard fill shall be used, and the surplus excavated material disposed of off the site.

Hard fill shall be GAP 65 laid in layers not exceeding 200mm and each layer compacted to a density of 90 per cent of the optimum dry density as defined by test 4.1 in NZS 4402.

Full use shall be made of hand-operated compaction tools on each side of the ducts and within a height of 0.6m above the crown of the ducts. Heavy construction equipment and heavy compaction plant shall not be operated over or near the ducts until backfilling is completed.

Compaction requirements for fill material and the specification for the types of allowable fill material shall be as per AS/NZS 3725 as a minimum.

4.8.1.8 Directional drilling or thrusting ducts

Ducts for cables under trafficked carriageways shall be installed by directional drilling or thrust boring.

The directional drilling or thrust shall be made to provide a minimum cover of 2m at any point under a main carriageway, or a minimum cover of 1.5m at any point under a ramp, along the length of the duct installed.

Before the design is complete, the designer must be satisfied that sufficient space is available to set up the drilling rig in order to reach the required depth before the drill passes beneath the carriageway. Additional permission may be required from adjacent landowners outside the highway designation for temporary access.

The duct routes installed by directional drilling or thrusting shall be kept as straight as possible.

All pits required for directional drilling or thrusting shall comply with the requirements for excavation and shall be kept as small as possible.

The ground surface at these pits shall be reinstated to the same condition as the adjacent surface.

Open ends of thrust ducts shall be kept plugged to ensure that material cannot enter the ducts.

Spoil from the drilling machinery and excavations shall be contained within the site, and shall not be permitted to enter stormwater drains, natural drains, streams etc. The contractor shall remove all spoil from the site at completion of drilling/thrusting at that site.

The minimum duct size for cross-carriageway thrusts is 100mm.

4.8.1.9 Jointing chambers and pull pits

The supply and installation of jointing cambers and pull pits and the connection of ducts into the chambers shall comply with the latest version of ITS design standard: Jointing chambers and pull pits.

4.8.1.10 Proving ducts

All ducts installed shall be proven as intact and free of obstacles by drawing a suitably sized mandrill through the length of the duct, once installation of the duct is complete. Any damaged areas shall be excavated, removed or repaired and retested until a satisfactory test is achieved.

4.8.2 ABF ducting

4.8.2.1 Type

Ducts shall comply with IEC 60794. Ducts manufactured to this standard must be independently certified and licenced.

4.8.2.2 Duty rating

There are no duty rating requirements for ABF.

The standards highlighted above define abrasion, kink, impacts etc.

They shall be sufficiently robust to resist the forces involved in thrusting and shall comply with <inset ref #>.

4.8.2.3 Colour (external sheath)

ABF ducting is designed solely for fibre-optic communications, so only salmon colour shall be used.

4.8.2.4 Print on duct

The backbone duct shall have the following information printed along its length at no more than 1m intervals:

- Waka Kotahi (or NZTA)
- the relevant standard the duct is manufactured to
- the batch number (may be on the microducts).

When installed, the print shall be face up.

Note: Microducts inside the ABF backbone duct do not require NZTA print.

4.8.2.5 Cover

In general, duct installation may be either directionally drilled, thrusted or laid in open cut trench. Where crossings of existing roads or the like is required, directional drilling or thrusting of duct shall be used as the preferred means to install ducts.

Minimum cover to ducts shall be as required for the duct situation as detailed in the latest version of ITS standard drawing 000-0000-0-7104-02-RX.

- 1m when alongside the carriageway (in the berm)
- 2m when crossing under a motorway carriageway
- 1.5m when crossing under a non-motorway carriageway.

4.8.2.6 Alignment

Duct routes shall be kept as straight as possible. Unless the manufacturer specifies a larger minimum bend radius, the minimum for microducts will be 10 times the nominal external radius of the microduct.

Note: Bends in ducts create friction when blowing cables. Multiple bends or a long cable blow can increase friction to unmanageable levels. Under no circumstances shall a cable be forced or pulled with a tension greater than cable manufacturer's recommended values, as this can lead to damage of the internal cores of the cable.

Where gradual curves are required in a duct system, the natural flexibility of a duct could be used to form the curve as long as it fits within the manufacturer's recommendations.

Where abrupt changes, (ie where the friction between the duct and the cable is sufficient that significantly reduces the length that the cable can be blown), of direction are required in the duct, a splice enclosure shall be installed.

4.8.2.7 ITS backbone ducts

4.8.2.7.1 General

In general, the ITS backbone ducts shall be in the highway berm parallel to the edge of the carriageway and ramp shoulders and shall be located outside any side protection barriers.

The main features of multiducting shall be:

- Two sizes of microduct are required, which will provide optimum blowing performance for the sizes of cable employed on the network.
- The fibre cables used by Waka Kotahi will typically be 96f or 48f for the backbone and 12f or 6f for spur cables. DAS cables can be as small as 2f, or more if the cable is to be used as a redundant ring.
- The sizes of duct will typically be 12–13mm OD/10mm ID for the backbone cable and 5mm OD/3.5mm ID for spur or link cables, though this may vary slightly between different manufacturers.

- The backbone duct shall consist of two or more 12mm OD/10mm ID + two or more 5mm OD/3.5mm ID high-density polyethylene (HDPE) microducts with ribbed surface inside tubes to reduce friction. The number of microducts will be determined by the required function of the duct.
- The number of microducts within the multiduct would be determined by the asset and joint densities on the network. It is expected that backbone and spur cable microducts will be sharing the same route and that at least two microducts are provided alongside the backbone microduct. Typically, a six-way duct would comprise three microducts of 12–13mm OD/10mm ID and three microducts of 5mm OD/3.5mm ID and a nine-way duct would comprise four microducts of 12mm OD/10mm ID and five microducts of 5mm OD/3.5mm ID, although other duct counts and combinations would be permissible.
- For feeder cables, a single duct may be used with either 12mm OD/10mm ID or 5mm OD/3.5mm ID HDPE tubing with ribbed surface inside tubes to reduce friction.

General ABF duct requirements are as follows:

- low-friction internal coating for maximum fibre blowing distance
- ripcord
- trace wire or sheath (copper, typical 0.9mm diameter + 0.5 sheath; or aluminium, typical 1.0mm diameter + 0.5 sheath)
- HDPE outer jacket (UV resistant) coloured salmon
- the duct must have the structural and tensile strength to resist the forces involved in thrusting and earth movement
- an anti-rodent protective layer may be specified where required.

4.8.2.7.2 Urban ducting

All existing urban ITS duct networks utilise conventional ducting systems with pull pits and chambers. It is recommended that the same format is used for new installations. Furthermore, urban ITS backbone networks generally require ducting for detector cables and power supplies in addition to fibre.

4.8.2.7.3 Rural ducting

Where there is little need for power and detector cabling, a single ABF duct may be provided. ITS assets generally receive their power from local sources and detection is generally limited to TMS sites, where a conventional ducting system may be provided alongside an air-blown ducting system.

The form of the ABF duct would therefore be suited to the network application. Typically, either nine-way or six-way ducting may be used.

4.8.2.7.4 Multiducting

Where ABF ducting is specified, a suitable multiduct shall be used. The multiduct installation shall be appropriate to the requirements of the ducting network.

Where the ducting is installed either as part of a motorway or expressway backbone duct network, or alongside a rural highway, it may either:

- replace one or more of the 32mm sub-ducts in the fibre duct. It shall run from joint to joint and the backbone microduct shall not be broken out in pull pits
- be provided alongside the ATMS 100mm ducting

- be provided on its own where only a fibre route is required and there is no foreseeable future requirement for non-fibre ducting.

A suitably designed direct-buried multiduct may be provided on non-motorway/expressway roads.

HDPE direct-buried multiducting shall be installed along the highway connecting to existing joint chambers at each end, for the backbone cable.

Where used, chamber locations shall be as specified in the latest version of ITS design standard: Jointing chambers and pull pits, section 4.1 Chamber locations. Pull pits are not required for this type of ducting.

A continuous duct length of at least 2km is required to minimise the need for in-line joints.

4.8.2.7.5 Mixing ABF ducting from different manufacturers

It is important to note that if the microducting of one manufacturer is joined to the microducting of a different manufacturer, the connector must be fully compatible with both ducting types. The designer must satisfy himself that the adjacent ducting types can be connected to manufacturers' tolerances for water tightness and continuity. Furthermore, the designer must be satisfied that the cable being blown through is compatible with both manufacturers' ducting systems.

Blowing a fibre of one manufacturer through the microduct of another manufacturer may limit the distance the fibre can be blown due to differences in texture and coating compatibility between the outer surface of the fibre and the inner surface of the microduct. In this situation, the installer must first satisfy himself that the fibre can be blown the required distance.

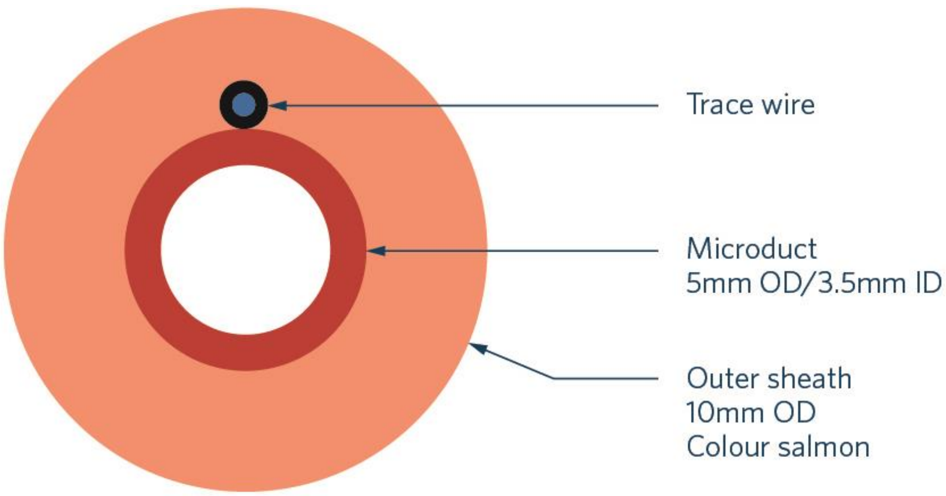
For this reason, it is recommended that any interface between different manufacturers' ducting and fibre cables takes place at a fibre splice enclosure/cabinet.

4.8.2.7.6 Microducting

If the system in use for the ITS backbone is ABF, one of the 5mm OD/3.5 mm ID microducts may be used where a spur cable runs on the backbone route. If the backbone route is not followed by the spur cable, the spur cable shall be in its own separate duct of equal ID.

A spur duct separate from the backbone duct shall be a one way direct-buried 3.5mm ID microduct. The OD would be determined by the thickness of the duct wall required for direct burying.

An example of a single microduct shall be as shown below. Note: A trace wire is shown, but a sheath may also be used.



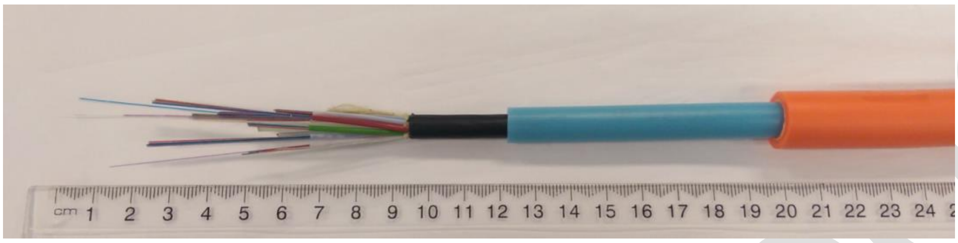


Figure 6. Example of a 96f micro-fibre in a single direct-buried microduct. The blue inner duct can be jointed using the appropriate connectors to a compatible microduct. The orange protective outer covering can be seen on the right.

4.8.2.8 ITS roadside cabinet connection ducts

4.8.2.8.1 Backbone to cabinet connection ducts

The method of ducted connection between the backbone and the communications cabinet depends on whether the fibre joint is a FIST-type joint situated in a jointing chamber, or whether the fibre joint is housed within an approved above-ground jointing cabinet.

If a FIST joint is used in a jointing chamber, either a single 6f or 12f ABF cable can be provided in a 10mm OD/6mm ID single duct, or a conventional 6f or 12f fibre cable can be run from the joint to the cabinet in a conventional duct.

If the joint is to be housed inside a jointing cabinet, a 6f or 12f ABF cable can be blown into the adjacent or nearby communication cabinet.

4.8.2.9 Local equipment connection ducts

4.8.2.9.1 ITS equipment connection ducts

Local duct connections from the roadside control cabinets to roadside devices shall use conventional ducting due to co-location with other services, short runs and the use of multimode fibre.

4.8.2.9.2 Cable pits and jointing (colloquially known as toby) boxes

Where the ABF duct connects into a ducting system requiring jointing chambers or pull pits, the supply and installation of cable pits and the connection of ducts into the pits shall comply with the latest version of ITS design standard: Jointing chambers and pull pits.

4.8.2.10 DAS ducts

4.8.2.10.1 Introduction

DAS is a method that can be used to locate moving vehicles along a transport corridor (road or rail) from vibrations that vehicles transmit through the ground to a buried fibre-optic cable. The fibre can be either an existing cable, or one installed specifically for the purpose.

This section deals with a duct installed along a carriageway specifically for DAS purposes.

The designer must be satisfied that the DAS fibre route is:

- located in a position where it will receive the best possible signal from passing traffic
- provides close coupling between the ground and the fibre in order that the fibre can detect as much traffic noise as possible.

A fibre along a road can be laid in one of two locations:

- Alongside the carriageway, on one or both sides, as close to the edge of the carriageway as practicable. This method is the most likely to be adopted where there is an existing backbone fibre route. Alternatives to this arrangement may include a DAS-only duct on one or both sides of a road, DAS-only and DAS/backbone ducts on either side of a road, or a DAS-only duct to bypass sections of backbone duct where the DAS is part of the backbone fibre cable where the main backbone deviates from the edge of the carriageway to a location where a signal is difficult to receive.
- Along the central median. This method may be used for lightly/moderately used carriageways of a motorway or expressway. It can be used as a bypass section where a DAS/backbone fibre deviates from the edge of the carriageway to a location where a signal is difficult to receive, or as a complete route in its own right. It provides equal signatures from both carriageways. A wide central median is not a suitable location as signal reception may not be achievable from both carriageways.

For motorways and expressways with two lanes in each direction, a fibre located in the median provides the best signal from both carriageways. The quality of this signal will deteriorate with a wider median, or wider carriageways. In situations where there is a lot of traffic, the carriageways are very wide or the carriageways are further apart, the best solution would be to install a fibre along either side of the road.

4.8.2.10.2 Duct type

A single tube ABF duct shall be used, which shall be directly buried and capable of not being damaged at a depth of 300mm. The duct shall comply with IEC 60794-x-x-x. Duct manufactured to this standard must be independently certified and licenced.

4.8.2.10.3 Duct size

For a DAS-specific cable, a 10mm OD/6mm ID primary tube will be optimal for a (minimum) two-core fibre to be blown for a distance of 3–4km.

This duct is suitable for burying in a berm or slot cutting into the carriageway.

4.8.2.10.4 Duct depth

Every method of installing ABF cable must use a ducted system. The optimum depth for burying the fibre is dependent on the burial method:

- slot-cut ABF duct into carriageway: 0.1m to 0.3m
- direct bury: DAS fibre cables may not be directly buried
- duct laid in berm/central median: 0.3m to 0.5m.

4.8.2.10.5 Duct offset

Generally, the further the fibre is located from the noise source the smaller the signal received. The main factor to consider when placing the fibre is physical distance from the lane(s) that need to be monitored. The detection equipment requires a certain amount of signal to work effectively. If the fibre is offset is greater than the manufacturer's recommendations, there is likely to be reduced system performance due to fewer detected vehicles being tracked.

Burial method	Offset from lane	Performance
Slot cut	<10m	Very good
	10m - 14m	Good
	14m - 17m	Average
Direct buried	<9m	Very good
	9m - 13m	Good
	13m - 16m	Average
Ducted	<8m	Very good
	8m - 12m	Good
	12m - 15m	Average

Figure 7. Recommended fibre offset for the various deployment methods.

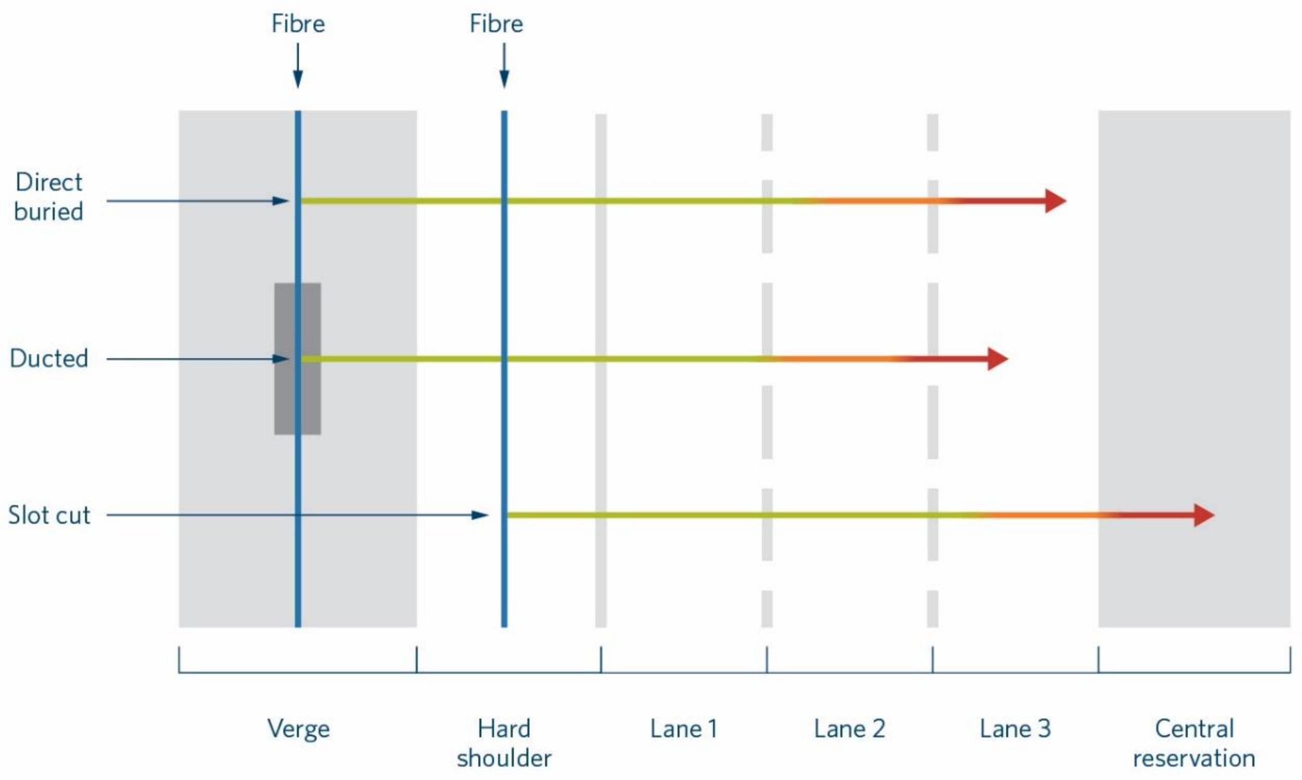


Figure 8. Fibre offset and burial type against DAS system performance. The colours of the arrows relate to the Performance column in Figure 7. above. This image is used for representation purposes only.

4.8.2.10.6 Installation technique

The duct can be installed by any means suitable for the location it is to be laid, including thrusting, trenching, micro trenching, chain digging or mole ploughing.

A suitably robust duct shall be used that will not become damaged by the passage of maintenance or wayward vehicles.

A superior signal will be received by the detection equipment if the DAS fibre has:

- close coupling to the ground, such as slot cut or direct bury
- is installed in firm ground conditions; the firmer the better.

However, for cable installation following capital projects, replacement or maintenance purposes, a ducted solution would be more convenient. The firmness of the ground around the duct will therefore be a factor in the signal strength obtained from the fibre.

The duct shall not be cast into a concrete barrier or in contact with the foundations of any barrier type due to the risk of transmitting vibration from within the barrier.

The median duct shall be connected to the roadside backbone fibre with the use of crossroad structures (under or over) or by thrusting a duct beneath the carriageway.

4.8.2.10.7 Chambers and duct splice enclosures

Duct splice enclosures shall be provided at a maximum of 3km intervals where the fibre may be fleeted from one duct length to another. A tube distribution closure shall be used in a kerbside junction box in accordance with latest version of ITS standard drawing 000-0000-0-7104-09-RX for fleeting purposes. All tube splicing connectors shall be manufactured by the same manufacturer as the duct and shall be IP68 rated. Suitable extended connectors may be used where kerbside junction boxes are used.

4.8.2.11 Draw cords or tapes

Draw cords or draw tapes are not required for ABF systems, as the fibre cable is blown into the microduct.

4.8.2.12 Trace wire

The air-blown microduct shall contain a built-in trace wire or sheath, therefore a separate trace wire will not be required.

Trace wire must be joined at duct joints and tested.

4.8.2.13 Plugging ducts

All unused tubes of microducting shall be plugged with suitable IP68-rated plugs produced by the same manufacturer as the microduct.

Microducts containing fibres must also be plugged where the fibre cable leaves the tube, using the following methods:

- 12mm OD/10mm ID tubes (used for 96f or 48f cables) shall use a suitable gas and water block, with triple O-rings and manufactured to IP68 rating.
- 5mm OD/3.5mm ID tubes which contain 12f or less cables may use epoxy lock and block which block gas, water and fibre movement. Where fibre movement is unlikely, a suitable rubber grip gas and water lock and block may be used.

4.8.2.14 Above-ground ducts

4.8.2.14.1 Concrete-encased ducts

Where it is impractical to install ducts in trenches with the minimum cover requirements, the ducts shall be encased in concrete.

Where the duct is above ground, the concrete cover to the ducts shall be a minimum of 50mm of concrete below and on each side of the ducts and a minimum of 100mm on top of the ducts.

Concrete for encasing the ducts shall be a minimum of 17.5 MPa compressive strength concrete.

Mark all such lengths of encased duct at intervals of approximately 25m with the legend ‘ITS Cables’ clearly imprinted a depth of 5mm in the concrete during finishing.

The concrete surface shall be trowel or float finished to provide a smooth surface.

H-branch enclosures or tube distribution closures shall be housed in an access box and shall not be encased in concrete.

4.8.2.14.2 Galvanised steel conduit

Where ABF ducts are exposed above ground and not encased in concrete, they shall be installed inside galvanised steel pipe conduit. The conduit shall be securely fixed in place with non-corroding, vibration resistant and UV-stable fixings. The design of the above-ground ducting shall consider the ability to install the multiducts or microducts (as necessary) around bends and deviations in the galvanised conduit (eg at bridges). Access plates or jointing boxes shall be provided where necessary for access purposes.

The size and numbers of galvanised steel conduits shall be sufficient to match the size and numbers of ducts provided. Generally, only one ABF multiduct is required, and the designer must consider the need to provide galvanised steel conduit for other services, such as power or detector cables.

All bends in the galvanised steel conduit shall be sweep bends with a minimum radius, which will be a function of the diameter of the tube and elongation required.

Bending radius = 0.5 x diameter of the tube / % elongation required. The % elongation =

- 42% for AKDQ steel
- 60% for annealed 304 stainless steel
- 33% for annealed 409 stainless steel.

Screw joints shall be fitted at 90-degree bends so the bend section can be removed for cable installation.

Galvanised ducting shall be earthed when passing close to power transmission lines or within 2m of railway overhead line electrification equipment.

The galvanised steel conduit shall be fixed with galvanised steel saddles at regular intervals of not more than 2m to the adjacent supporting structure.

All galvanised steel conduit shall be proved and have trace wire and draw tape installed.

Figure 9. Typical galvanised steel ducting on the side of a bridge.

Galvanised steel conduit shall not be attached to safety rails or rail posts or interfere with their performance in the event of a crash.

4.8.2.15 Storage and handling

Handling and storage of ABF ducting must be carried out in line with IEC 60794 and the manufacturer's handling instructions

4.8.2.16 Trenching

4.8.2.16.1 Excavation

All excavations for trenches shall be to the lines shown on the drawings and to such directions as may be given by the engineer.

The excavations shall be open trenches unless the written permission of the engineer is obtained for other construction methodology.

Not more than 100m of trench shall remain open at one time unless otherwise approved by the engineer.

In excavating trenches, any surfacing materials shall be salvaged and stockpiled as far as possible so as to be replaced after the trench has been backfilled. Any surfacing materials lost shall be reinstated by the contractor at his own expense.

All spoil from the trench shall be kept away from the edge of the trench at the top to avoid overloading the trench sides and to comply with the HSE Act regulations.

4.8.2.16.2 Surface cutting

The edge boundaries of trenches and excavations shall be marked on the surface in a line type or colour that is different from markings for existing services.

In sealed areas the sealed surface shall be neatly saw cut, set back from the edge of the excavation. The setback shall be 150mm for a trench width of 30mm or less, and 300mm elsewhere. In unsealed areas the edge of the surface opening shall be kept as neat as possible.

Where the surface consists of cobblestones or pavers, these shall be carefully removed and stored for reinstatement. Any damaged paver units shall be replaced by the contractor.

Should the sides of the excavation slump or the surface surrounding the edge of the excavation become depressed, then the cut shall be opened wider until a stable sub-surface is found. This additional excavation shall be at the contractor's cost.

4.8.2.16.3 Dewatering trenches

The contractor shall maintain all trench bottoms free from flowing or accumulated water, so that all ducts can be bedded, laid and jointed in dry working conditions.

The contractor shall provide sufficient labour and plant, and maintain all drains, pipes, pumps and sumps to keep the works clear of water to the satisfaction of the engineer.

All water shall be disposed of to the approval of the engineer and any damage caused shall be made good by the contractor at its own expense.

4.8.2.16.4 Support of trenches

All work involving excavations must comply with the requirements in the HSE Act and HSE Regulations.

Excavations shallower than 1.5m

Excavations shallower than 1.5m shall not necessarily be regarded as safe from the risk of collapse. The contractor shall consider such excavations on a case-by-case basis and determine if special precautions or work methods are necessary.

Excavations 1.5m or deeper

Excavations equal to or greater than 1.5m deep are particularly hazardous and must be supported or benched back to a safe slope, as determined by the contractor, in accordance with HSE Regulations.

4.8.2.16.5 Duct installation in trenches

ABF ducting shall be installed in line with AS/NZS 2032:2006 Installation of PVC pipe systems, AS/NZS 2033:2008 Installation of polyethylene pipe systems and AS/NZS 2566 requirements. In addition, the installer shall follow the manufacturer's installation instructions and guidelines.

4.8.2.16.6 Jointing ducts

Ducts shall be joined in approved H-branch or tube distribution enclosures which shall be directly buried wherever possible. These enclosures shall be sourced from the same supplier as the ABF ducting.

H-branch enclosures are IP68 rated and may be directly buried or installed within a chamber.

Tube distribution closures are IP47 rated and may be directly buried only.

An appropriate enclosure shall be specified and used for the type of joint required.

If two lengths of ABF ducting or multiducting are to be connected end to end, a straight-through enclosure shall be used.

Where multiducts or microducts are to branch from the backbone, a suitably sized and shaped enclosure shall be used.

When joining or connecting to the ABF backbone duct, using a splice enclosure, remove an adequate amount of outer sheath to ensure inner microduct can be pushed past the O-ring in the splice enclosure assembly. Ensure that all surfaces are clean and free from soil, debris or other contaminants before closing a splice enclosure. Ensure that no part of the cut surface of the outer sheath of the duct is outside the enclosure or within 10mm of the compression gland of the splice enclosure.

Microduct 'stripping' for branching and jointing is not stated in standards but is described in manufacturers' work instructions.

Any enclosures, plugs, connectors or any other apparatus used to connect or encase the ABF duct or its microducts shall be of the same manufacturer in order to maintain IP rating and integrity of the ABF network.

Ducting and fibre from one manufacturer may interface with that of another manufacturer only at FIST joints or jointing cabinets.

Figure 10. Example of a commercial (green) direct-buried ducting connector being installed. These connectors allow a spur to be broken out of the duct line. The spur itself is broken out from the backbone fibre at an upstream joint. The spur fibre is thus blown from joint to asset through this connector. This enclosure is directly buried into the trench (visible on the right). These are green ultra-fast broadband ducts.

4.8.2.16.7 Protection

Marker (warning) tape to AS/NZS 2648.1:1995 Underground marking tape – Non-detectable tape is required by AS/NZS 3000:2018 Australian/NZ Wiring Rules, section 3.11 Underground wiring systems. It shall be installed above all trench-laid ducting containing underground wiring. The tape shall be installed at 50 per cent of the depth of the duct. Thrusted or bored PE duct is exempt from the marker tape requirement.

A cable cover will not normally need to be installed above an ABF duct.

However, when used, the cable cover shall be centrally positioned above the duct and shall be twice the width (diameter) of the duct it is protecting.

4.8.2.16.8 Backfilling of trenches

Ducts in trenches shall be backfilled over as soon as is practicable after they have been laid, bedded and jointed as specified.

Excavated materials shall only be used for backfilling where the excavation to be backfilled is in a grassed or planted berm.

In sealed or unsealed roadways, driveways or footpaths, hard fill shall be used, and the surplus excavated material disposed of off the site.

Hard fill shall be GAP 65 laid in layers not exceeding 200mm and each layer compacted to a density of 90 per cent of the optimum dry density as defined by test 4.1 in NZS 4402.

Full use shall be made of hand-operated compaction tools on each side of the ducts and within a height of 0.6m above the crown of the ducts. Heavy construction equipment and heavy compaction plant shall not be operated over or near the ducts until backfilling is completed.

Compaction requirements for fill material and the specification for the types of allowable fill material shall be as per AS/NZS 3725 as a minimum.

4.8.2.17 Directional drilling or thrusting ducts

Ducts for cables under trafficked carriageways shall be installed by directional drilling or thrust boring.

The directional drilling or thrust shall be made to provide a minimum cover of 2m at any point under a main carriageway, or a minimum cover of 1.5m at any point under a ramp, along the length of the duct installed.

Before the design is complete, the designer must be satisfied that sufficient space is available to set up the drilling rig in order to reach the required depth before the drill passes beneath the carriageway. Additional permission may be required from adjacent landowners outside the highway designation for temporary access.

The duct routes installed by directional drilling or thrusting shall be kept as straight as possible.

All pits required for directional drilling or thrusting shall comply with the requirements for excavation and shall be kept as small as possible.

The ground surface at these pits shall be reinstated to the same condition as the adjacent surface.

Open ends of thrust ducts shall be kept plugged to ensure that material cannot enter the ducts.

Spoil from the drilling machinery and excavations shall be contained within the site, and shall not be permitted to enter stormwater drains, natural drains, streams etc. The contractor shall remove all spoil from the site at completion of drilling/thrusting at that site.

The designer should be satisfied that the ABF duct is suitable for thrusting purposes and the minimum duct size used for thrusting should contain multiple microducts.

For future-proofing purposes, when thrusting under a carriageway, it is recommended that at least one conventional 100mm duct is installed at the same time. If it is not for immediate use, it shall be plugged in order to stop material entering.

4.8.2.18 Chain digging or mole ploughing

ABF ducts are smaller than conventional ducts and are generally installed in areas where mole ploughing or chain digging is a viable and quick option. However, this option is not without its hazards, so the location of any buried services or drainage paths shall be thoroughly investigated before commencing mole ploughing or chain digging.

Refer to manufacturer's work instructions and product specifications to ensure that the subject installation method is suitable for the product (tensile strength, bend etc).

4.8.2.19 Mole blowing

This method of installation is not recommended for ABF ducting as it can over-stress the duct.

4.8.2.20 Jointing chambers and pull pits

Where used, the supply and installation of jointing chambers and pull pits and the connection of ducts into the chambers and pits shall comply with the latest version of ITS design standard: Jointing chambers and pull pits.

4.8.2.21 Proving ducts

ABF ducting shall be tested for continuity using an approved method (such as the ball chain or sponge test method) and pressure tested as per manufacturer's recommendation.

Note: It is not recommended or an accepted practise to use 'ball bearing' as a method of testing ducting in the field due to potential health and safety issues. After duct integrity testing is complete, ducts should always be sealed at both ends with suitable end connectors and/or end caps.

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.

6 DESIGN FOR MAINTAINABILITY

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

6.1 Maintenance outcomes

6.1.1 Draw cord or tape

Draw cord or tape shall be installed in all ducts and within one sub-duct to facilitate the hauling in of cable after the completion of the ducting.

Alternatively, each duct may be fitted with a pigmented, stranded polypropylene or equivalent rot-proof material draw cord or tape of 5kN breaking load and having a design life of not less than 20 years, the ends of which shall be made fast within the chambers to which the duct is terminated. Draw cords or tapes shall be secured to the duct plugs. Draw cords or tapes shall not be knotted within ducts; where a joint is required it shall be a spliced joint.

All ducts and conduits used or unused shall be left with a draw cord or tape in place.

6.1.2 Trace wire

A trace wire shall be installed:

- either separately or integrated into one of the backbone fibre-optic cable ducts in the space between the sub-ducts and the main duct
- in all local fibre-optic cable ducts.

The trace wire shall be a copper-based wire with at least two conductors of 1.5mm^2, individually insulated, overall insulated. This is not applicable to pre-installed co-extruded trace wire.

6.1.3 Plugging ducts

Cable ducts entering chambers shall be trimmed such that they protrude no more than 40mm from the chamber wall and sealed to avoid water seepage.

After installation of cables, all duct (but not sub-duct or microduct) entrances shall be filled with a watertight, non-hardening sealant that can be removed as necessary in future to install more cabling.

All unused ducts, sub-ducts and microducts shall be plugged with removable plugs or tight-fitting caps to prevent ingress of water and soil.

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 Applicable standards – conventional ducting

10.1.1 PE duct type

10.1.1.1 Manufacturing standards

Standard number / name	Source	Licence type and conditions
AS/NZS 61386 Conduit systems for cable management (running in parallel with and to eventually supersede AS/NZS 2053)		
AS/NZS 4130:2018 Polyethylene (PE) pipes for pressure applications		
AS/NZS 2648.1:1995 Underground marking tape – Non-detectable tape		
AS/NZS 4327:1995 Metal-banded flexible coupling for low-pressure applications		
AS/NZS 4129:2020 Fittings for polyethylene (PE) pipes for pressure applications		
NZS 4402		
AS/NZS 3725		

10.1.1.2 Installation standards

Standard number / name	Source	Licence type and conditions
AS/NZS 3000:2018 Electrical installations – Known as the Australian/New Zealand Wiring Rules)		
AS/NZS 2033:2008 Installation of polyethylene pipe systems		
AS/NZS 2566 Buried flexible pipelines		
AS/NZS 2033:2008 Installation of polyethylene pipe systems		
Plastic Industry Pipe Association (PIPA) Guidelines for Joining PE & PVC Pipe – PIPA POP Guidelines		

10.1.2 PVC-U duct type

10.1.2.1 Manufacturing standards

Standard number / name	Source	Licence type and conditions
AS/NZS 61386 Conduit systems for cable management (running in parallel with and to eventually supersede AS/NZS 2053.2:2001 Conduits and fittings for electrical installations – Rigid plain conduits and fittings of insulating material)		
AS/NZS 2053.2:2001 Conduits and fittings for electrical installations – Rigid plain conduits and fittings of insulating material (running in parallel with AS/NZS 61386.21)		
AS/NZS 2648.1:1995 Underground marking tape – Non-detectable tape		
AS/NZS 3879:2011 Solvent cements and priming fluids for PVC (PVC-U and PVC-M) and ABS and ASA pipes and fittings		
AS/NZS 4702 Cable cover requirements		
AS/NZS ISO 14001 Best Environmental Practice (BEP) Guidelines for PVC in the Built Environment detailed as part of the Green Star PVC Credit version 1		

10.1.2.2 Installation standards

Standard number / name	Source	Licence type and conditions
AS/NZS 3000:2018 Electrical installations – Known as the Australian/New Zealand Wiring Rules)		
AS/NZS 2032:2006 Installation of PVC pipe systems		
AS/NZS 2566.2:2002 Buried flexible pipelines – Installation		
D2855 Standard Practise for Making Solvent-Cemented Joins		
AS/NZS 1260:2017 Appendix C PVC-U pipes and fittings for drain, waste and vent applications – Appendix C		
AS/NZS 2032:2006 Code of practice for installation of PVC-U pipe systems		
Plastic Industry Pipe Association (PIPA) Guidelines for Joining PE & PVC Pipe		
AS/NZS 2566 Buried flexible pipelines		

10.2 Applicable standards – ABF ducting

Standard number / name	Source	Licence type and conditions
IEC 60794-1-2-E2B Abrasion resistance of optical fibre cable markings		
IEC 60794-1-2-E10 Kink		
IEC 60794-1-2-E4 Impact		
IEC 60794-1-2-E3 Crush		
IEC 60794-1-2-E1 Tensile performance		
IEC 60794-1-2-E11 Bend		
IEC 60794-1-2-E7 Torsion		
IEC 60794-1-2-E8 Flexing		

Note: IEC 60794-1-2-EXX standards are about optical cable and microduct test methods.

10.3 Waka Kotahi standards, specifications and resources

10.3.1 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 design standard: Jointing chambers and pull pits
ITS design standard: Ramp meter systems

10.4 Drawings

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

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

Drawing reference
000-0000-0-7104-02-RX
000-0000-0-7104-09-RX

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