Upgrading Old Ducts for New Optical Connections

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Abstract

Assemblies of microducts offer cost savings that help us to bridge the recess in Telecommunications. Bundles of 4, 7 and 10 mm microducts can be jetted (blown) into newly installed or old ducts (avoiding digging), also when occupied with resident cables. They can be installed much more easily than cables (less weight, less wedging, easy to couple and hence avoiding inefficient buffering of short lengths). Microduct cables, with up to 72 fibres each, can be jetted in these high quality microducts (low coefficient of friction, high pressure resistance) over spliceless lengths of up to 8 km. Further cost savings are obtained by the pay-as-you-grow possibility and the versatile branching of the microduct assemblies.

1 Introduction

Due to the worldwide recess in Telecommunications investments in fibre optic networks have decreased dramatically. Besides, during the past few years a lot of fibre overcapacity has been installed. Therefore today installation of new optical links does not occur very often. But, sometimes networks need extensions and they shall be done at minimal costs. Because civil works are the largest cost contributors existing duct routes are used as much as possible.

Existing duct routes may be of poor quality. Not only they may be old and worn out, often they were constructed for copper cables. Here short lengths of cable were pulled in with high forces and numerous splices were made to connect them. Fiber optic cables are installed now over much longer lengths, on the order of 10 km between splices. Modern ducts are of improved quality resulting in lower coefficient of friction (COF) between cable and duct. Together with the development of the jetting (blowing) technique [1] this resulted in cost-efficient installation of optical cables over the required lengths.

Old ducts suffer from high COF, especially after long-term aging. They are often not able to withstand the air pressures needed for cable jetting. Numerous connections must be made between short duct sections to allow installation of long cable lengths. This is especially a problem when the ducts were cut immediately after entering the handhole, making it almost impossible to connect the ducts sufficiently pressure-resistant to allow jetting.

All these problems are faced to a larger extent when resident cables occupy the ducts. Air tight duct connections are difficult to make because of this cable, usually with traffic. Moreover the installation length is very small because of wedging of the new cable between the old cable and the inner duct wall. In many cases the inter handhole distance cannot be bridged and digging the street is needed.

In this paper a solution to above mentioned problems is described. Bundles of microducts (4, 7 or 10 mm external diameter) are installed by jetting [2]. They are easily coupled to longer lengths of low COF and high pressure resistance. This allows jetting of long lengths of optical cable (up to 72 fibres per cable) without splice. The microduct assemblies also further reduce the costs due to the pay-as-you-grow principle and the versatile branching.

2 Microduct Assemblies

Microduct (outer diameter 4, 7 or 10 mm) assemblies consist of loose bundles of microducts (see **Fig 1**). These bundles can be jetted (synergy of pushing and blowing) in protective ducts such as used today for installation of fibre optic cables. Jetting lengths for bundles of microducts are typically 200 m per bar air pressure (for the recommended filling degree). In good quality ducts more than 1500 m can be reached "in one blow". Bundles of microducts can be coupled by means of simple connectors. Branching of one or more of the microducts is possible by making a window-cut in the protective duct, cutting the microduct of choice and connecting it to a branching microduct. The protective ducts are recovered by using a (split) clip-on Y-connector (see **Fig 2**). This operation can be done without risk of damaging the other microducts. Microduct-cables with extremely high fibre-density (up to 72 fibres) can be jetted in these microducts, each cable having its individual path through the network, without the need to make splices in the optical fibres.

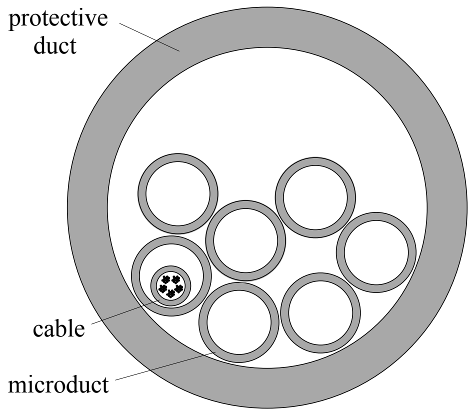

Fig. 1 Typical microduct assembly: 50/40 mm protective duct with 7 microducts of 10 mm and a 72-fibre cable

Jetting technology allows installing lengths of the cables of up to 2500 m "in one blow". With cascaded jetting (tandem, see **Fig 3**) and buffering techniques more than 8 km splice-less cable lengths have been installed.

Fig. 2 Y-connector to branch microducts

Some advantages of assemblies with loose bundles of microducts are:

- Investments grow with demand. Pay as you grow.
- Installation of latest fibre optic technology.
- Midspan-access at any place and any time. Fibres with traffic not disturbed.
- Fast installation technology and short response time.
- Possibility of re-routing without lost fibres or splicing.

Fig. 3 Jetting microduct cables in tandem

The number of microducts is advised to be such that half the space of the duct is filled, see Table 1. In this way the duct still gives the required mechanical protection (impact resistance) and Y-branching and jetting of the bundle are made easy.

Table 1 Recommended maximum number of tubes and fiber counts for different ducts

duct (mm)	10 mm tubes	max fibres	7 mm tubes	max fibres	4 mm tubes	max fibres
63/50	10	720	20	480	48	192
50/40	7	504	14	336	36	144
40/33	5	360	10	240	24	96
32/25	3	216	7	168	12	48
25/20	1	72	3	72	6	24

A reference project (i.e. with good quality ducts and no resident cables) is installation of 10 tubes of 10 mm in empty 60/50 mm ducts between San Diego and Phoenix. Bundles were installed in lengths of about 1000 m, usually a few of those sections per day. Many splice-less lengths of 8 km of 60-fiber cable have been installed (one-day jobs), using tandem jetting and buffering (see **Fig 3** and **Fig 4**). Note that this installation was done with loops of cable-overlength stored in handholes about every 400 m.

Fig. 4 Jetting microduct cables with buffering

3 Additional Jetting

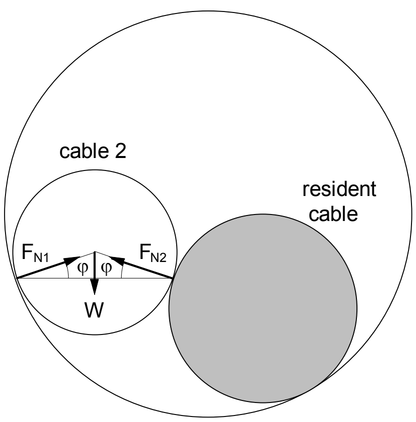

Fig. 5 Forces on a second cable

Installation of second cables (diameter D_{c2}) next to resident cables (diameter D_c) in a protective duct (inner diameter D_d) can be done by means of rodding, pushing and/or jetting. In all cases installation lengths are limited by the high wedging effect of the new cable between the resident cable and the inner wall of the protective duct. The resulting normal forces F_{N1} and F_{N2} are drawn in **Fig 5**. The factor f_{wedge} with which the friction force increases with respect to the situation of sliding over a flat surface is given by [3]:

$$f_{wedge} = \sqrt{\frac{(D_c + D_{c2})(D_d - D_{c2})}{D_{c2}(D_d - D_c - D_{c2})}} \qquad (1)$$

This factor reaches a minimum for a value D_{c2} of:

$$D_{c2,opt} = \frac{1}{2}(D_d - D_c) \qquad (2)$$

The big wedging effect for a relatively small second cable is clear. It will fall deep into the wedge where the (contact) walls of resident cable and duct become more and more parallel. But, also for a relatively large second cable the walls become almost parallel (close to exactly fitting) and again a high wedging will be experienced.

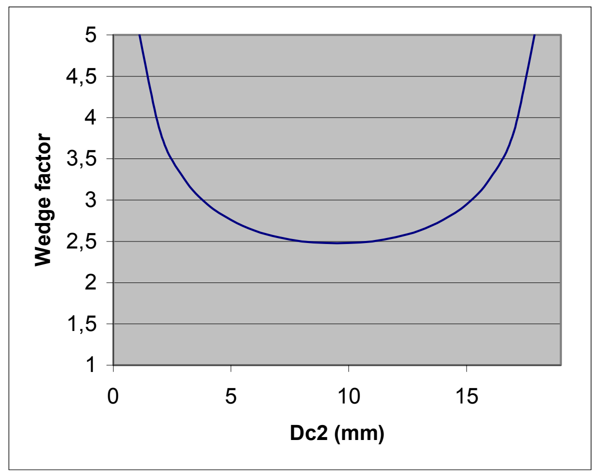

Fig. 6 Wedge factor as a function of diameter D_{c2} of second cable in 40/33 mm duct with resident 15 mm cable

In **Fig 6** a typical example is given. Note the symmetry. Minimal wedging for a second cable at a diameter of 9 mm, in the range of 7 and 10 mm microducts, is surprising (one intends to think that larger cables suffer less from wedging). Besides the weight of microducts is much less than that of cables, hence longer jetting lengths are to be expected.

Moreover short sections of microduct can be installed and coupled to long continuous routes without the need for jetting with tandem operation and/or buffering at many places. Such inefficient installation would be needed for additional jetting of spliceless cable lengths.

An overview of additional jetting lengths for different bundles of 7 and 10 mm microducts in 40/33 and 50/40 mm ducts with different resident cables is given below.

Table 2 Jetting distances (m) for 10 mm tubes in 40/33 mm duct with resident cable

cable 1 (mm)	1 tube	2 tubes	3 tubes	4 tubes
12	1200	1100	950	800
15	700	600	550	
16.5	400	400		
18.5	200	200		

Table 3 Jetting distances (m) for 10 mm tubes in 50/40 mm duct with resident cable

cable 1 (mm)	1 tube	2 tubes	3 tubes	4 tubes	5 tubes	6 tubes
12	1600	1500	1300	1150	1000	900
15	1200	1100	1000	850		
16.5	800	800	750	700		
18.5	400	400	400	400		

Table 4 Jetting distances (m) for 7 mm tubes in 40/33 mm duct with resident cable

cable 1 (mm)	1 tube	2 tubes	3 tubes	4 tubes	5 tubes	7 tubes
12	900	1000	1000	1000	900	800
15	350	450	500	500	500	450
16.5	250	250	300	300	300	
18.5	200	200	200	200		

Table 5 Jetting distances (m) for 7 mm tubes in 50/40 mm duct with resident cable

cable 1 (mm)	2 tubes	5 tubes	7 tubes	9 tubes	10 tubes	12 tubes
12	1600	1350	1200	1050	950	600
15	700	850	750	600	550	400
16.5	400	500	450	400	350	
18.5	200	250	250			

In **Fig 7** an example is shown of a 40/33 mm duct occupied with a 15 mm resident cable in which 3 additional 10 mm tubes were installed (possible over 550 m, see Table 2). Note that the partial filling of the duct with cable and tubes still guarantees resistance against impact. 10 mm corresponds to about the minimum wedge factor, see **Fig 6**. The 3 tubes can store 3 cables with up to 72 fibers, a total of 216 fibers. An additional cable with this fiber count would be very difficult to install.

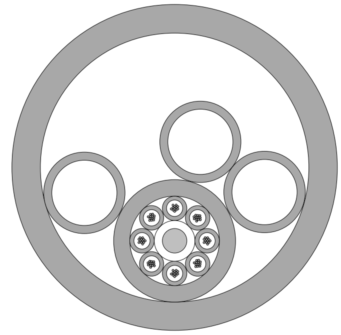

Fig. 7 40/33 mm duct with 15 mm resident cable and 3 tubes 10 mm

4 Projects

4.1 Wuhan

In Wuhan (China) a trial was done in thin-walled 32 mm PVC duct. Here 7 tubes of 7 mm were installed over 500 m using only 2 bars. More pressure was not allowed. Expansion of the ducts and serious leaking already occurred. The newly installed mini-tubes eliminate these problems.

4.1 San Jose

A short but challenging installation was done in San Jose, California. Here an installation was requested over 400 m in a 42/34 mm duct with 2 resident cables (12 and 15 mm) with traffic. The civil and permitting costs that would be involved in digging up this portion of the route was prohibitive. Previous to our arrival several attempts, including the use of rodders, were done to install a third cable, all without success. Shown in **Fig 8** is the duct with cables in the handhole. Note the damage to the duct, caused by the rodder (right in the picture). Some debris (only a small portion of the total encountered) can be seen at the end of the rodder, caused by scraping against the duct wall.

Because the duct was of poor quality it was decided to install only one 10 mm tube next to the cables (in good condition additional jetting of 2 tubes would be possible over 600 m in this geometry). During installation several additional problems were encountered. First the duct was leaking halfway. Next obstructions were present at three different locations in the duct, probably caused by debris from previous attempts with rodders. Also no aftercooler was present with the compressor, resulting in temperatures of about 60 degrees Celsius of the airflow, softening all materials. Nevertheless the tube could be installed and a 48-fibre cable was blown in immediately after (**Fig 9** and **Fig 10**). The whole project was finished in slightly more than two days, including splicing to other cables. The majority of time was spent cleaning from previous attempts. Actual installation of the guide tube and cable took only 1/2 day.

Fig. 8 Duct occupied with 2 resident cables

Fig. 9 Mounting Y-piece for additional jetting with 2 resident cables and guide for the tube

Fig. 10 Installed additional tube and cable

4.2 Gothenburg

On a trajectory of about 3 km near Gothenburg, Sweden there was a demand for extra fiber capacity. Here a fiber optic cable with a diameter of 14 mm was already present in a 40/33 mm duct. An initial attempt to install an additional 96-fibre cable with a diameter of 15 mm was not successful in that it only reached 150 m. Instead 3 tubes of 10 mm were jetted in (see **Fig 11**). This was installed in slightly more than 2 days, with lengths per blow of up to 512 m. This length is somewhat less than expected. This might be caused by the fact that a lot of water was present in the duct, caused by the many duct openings resulting from the previous trials with cable.

In each of the 10 mm tubes a cable with up to 72 fibers can be jetted in easily (up to 2500 m in one blow). One cable was successfully installed over 3 km, without splice, jetted with one master and one tandem-jetting device.

Fig. 11 Additional jetting of 3 tubes of 10 mm

4.3 Copenhagen

A trajectory of 1137 m of 32/27.2 mm duct was occupied with a single resident 12 fibre cable with diameter of 10.9 mm over 755 m. Over a length of 32 m even 2 resident cables were present. In the free duct section a bundle of 4 tubes of 10 mm was jetted in. In the section with single resident cable a bundle of 2 tubes of 10 mm was installed in a single blow, see **Fig 12** and **Fig 13**. The same bundle was pushed in by hand over the remaining double occupied duct section. Next a 60-fiber cable was blown in over the entire length. The whole operation took only 1/2 day.

Fig. 12 Additional jetting Copenhagen

Fig. 13 Detail Copenhagen

5 Conclusions

Assemblies with loose bundles of 4, 7 and 10 mm microducts can upgrade old duct routes. The microducts can easily be coupled to longer lengths in which micro duct cables with up to 72 fibres per tube can be installed with high performance. Bundles of microducts can even be installed in occupied ducts, next to resident cables with traffic. Installation lengths per blow are, surprisingly, much longer for additional microducts than for cable. In addition to this benefit longer lengths are achieved by using coupling of the tubes.

6 Acknowledgements

Special thanks to all people participating in the trials and projects: Maja Keijzer, Cees van 't Hul, Ignaat Eijpe, Danny Bisessar, Frank de Bruin, Bert van der Tuuk, Kenneth Crowe, Nancy Li, Yang Zhanbing (Draka Comteq), Bill Bolle (Tier2), Michael van Moppes (Plumettaz), Roland Ahl, Tobias Ahl, Per-Anders Andersson (Rala) and JJ Johnson (Triax communications).

7 Literature

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