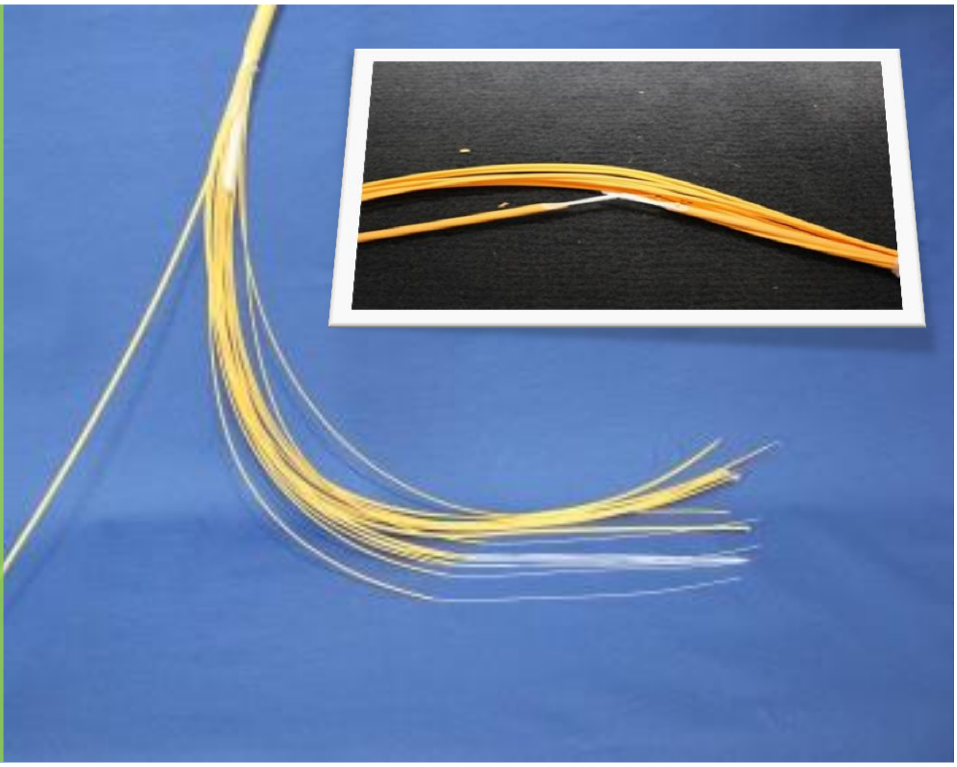
fibre optics

CT Consulting & Testing GmbH

News 00/04



Should the quality assessment of an optical multi-fibre splitter cable for indoor installation be carried out according to DIN EN 60794-2-20/ 60794-1-21 or the client's technical data sheet?

Current standards state that the conditions and requirements regulating the operational performance of an optical cable should be decided on between client and supplier.

As a client, what do you think about this?

Test requirements and conditions are to be agreed upon with the supplier. But should this be …

☐ ... in accordance with technical specifications with special requirements?

☐ ...or with reference to all current standards and testing requirements?

We would like you to write and tell us what your experience has been!

A General information required by Fibre Optics CT GmbH to judge the performance of an optical cable under operational conditions

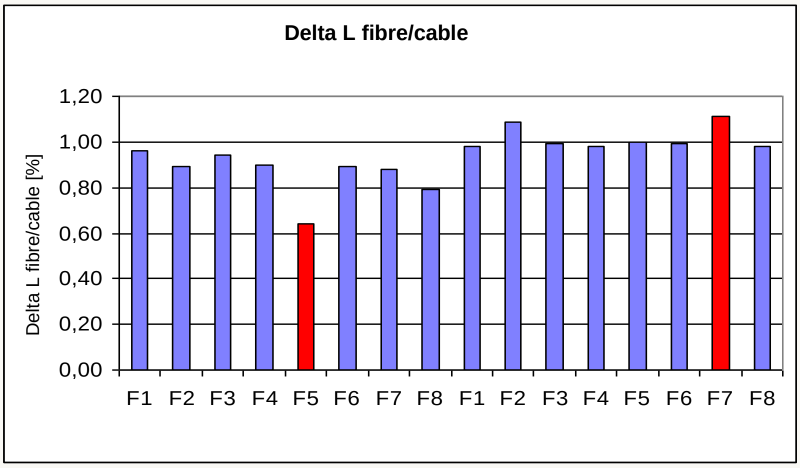
a. Cabled fibre overlength at RT: ___‰
b. Fibre (shortest/ longest) elongation εF starts at: ____ N
c. Start of cable elongation: ______ %
d. Start of attenuation change Δα in shortest/ longest and in fibres joined in series, in tests of tensile strength and cable bending test under tension: _____ dB
e. Attenuation change Δα at highest/lowest temperatures at cable ends and in the cable: _____ dB
f. Attenuation change Δα, as the cable ages. Cable bending in the actual area of operation _____° if required by the client.
g. Reversibility of the property changes referred to in a to f

B Example: "cabled fibre overlength" (test results on a bundle-stranded cable)

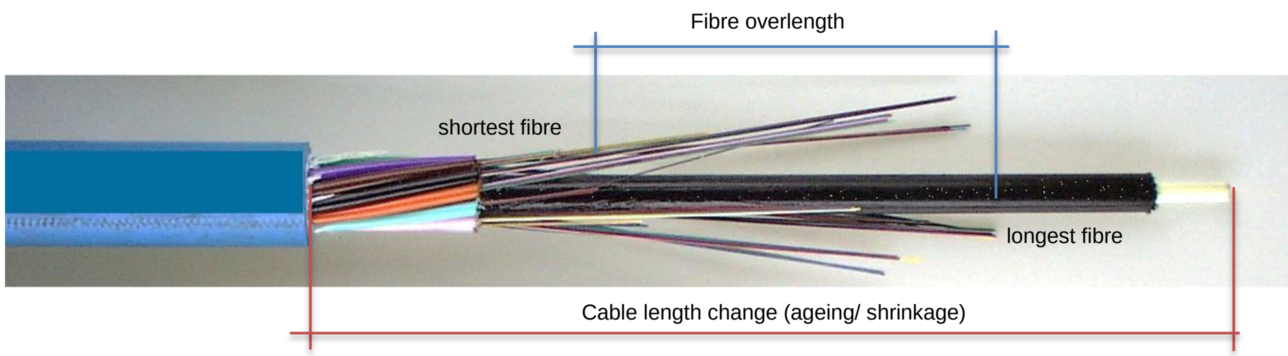
Cable length 13.220 mm

Fibre length:
min: core 1, fibre 5
13.305 mm
max. core 7, fibre 7
13.366 mm

Δl min/max length:
actual 0.5456%
specified < 0.1%



Requirement according to standards: none
according to Fibre Optics CT GmbH: extremely important

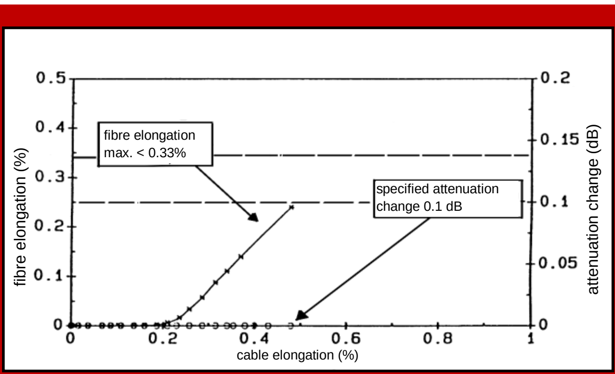


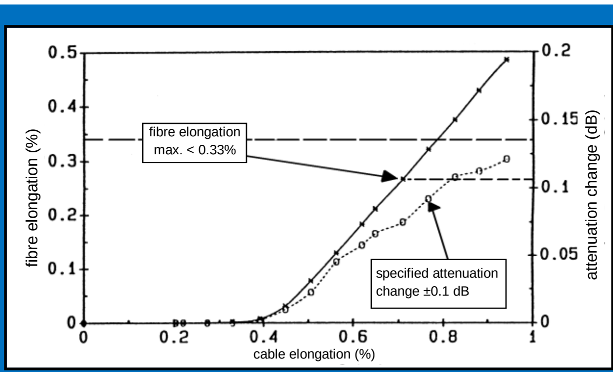
Cable length change (based on DIN EN 60794-1-22 /F9)
This test method is used for all optical cables undergoing temperature cycling, in order to estimate the effect on service life of attenuation at connection points.

Requirement according to standards: none
according Fibre Optics CT GmbH (FO): extremely important. FO specification: < 0.3%

C General quality characteristics demanded to current technology

Fibre elongation εF (shortest fibre) and attenuation change as a factor in cable elongation





Cable with central loose tube
A-D(ZN)2Y 1x10 E9/125...zD

- calculated fibre overlength 0.2%
- max. admissible attenuation change under tensile stress [dB]
  SM fibres in 1310 nm ≤ 0.05 dB range

Cable with layer-stranded loose tube (S/Z stranding)
A-DF(ZN)2Y 4x2 E9/125...Lg

- calculated fibre overlength
  - S/Z-stranding 0.37 %
  - helical stranding 0.45 %
- max. admissible attenuation change under tensile stress [dB]
  SM fibres in 1310 nm < 0.05 dB range

Source: Wenzki Kabelmetall electro

Values based on experience:

The results shown above correspond exactly to current test results obtained by the MTS Messtechnik Service K. Kimmich (physicist), Stuttgart

Requirements:

DIN EN 60794-3:2002 Section 5.2.2 "Sudden increases in attenuation"
Attenuation should at no point increase by more than 0.1 dB.

Section. 9 "Testing optical cables"
According to this standard, the measurement error for attenuation should not exceed 0.05 dB.

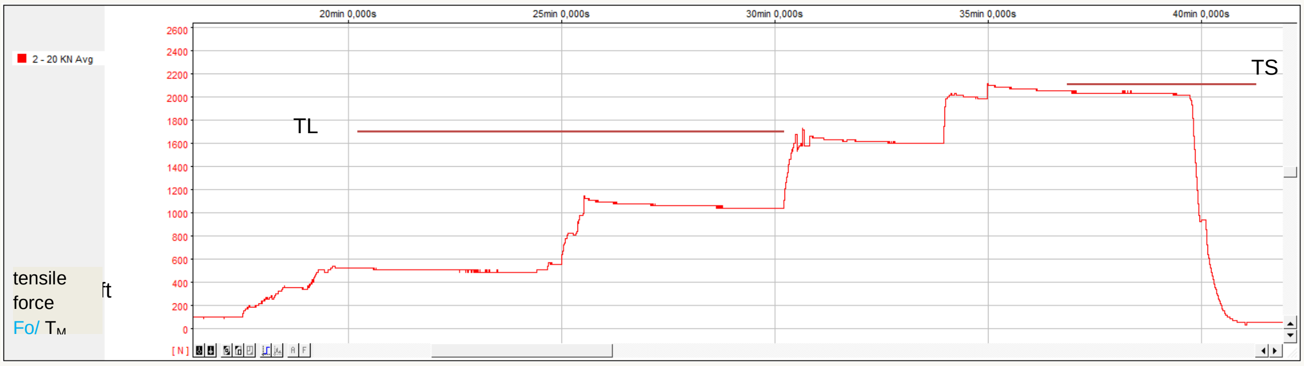
DIN EN 60794-3-10: 2002
Table 4.2.1 Single-mode fibres (B1.1)
Sudden increases in attenuation at 1310 nm and 1550 nm

What would you have decided on with your supplier regarding the tensile strength of this cable and cable bending under tension?

1. Test procedure and evaluation as required by the standards?
2. Or according to technical delivery specifications with special requirements?

Example: an optical multi-fibre splitter cable with single-mode fibres in conformity with DIN EN 60794-2/ 60794-2-20

Comparison 1: Tensile force TS (short-term) and TL (long-term) [N]

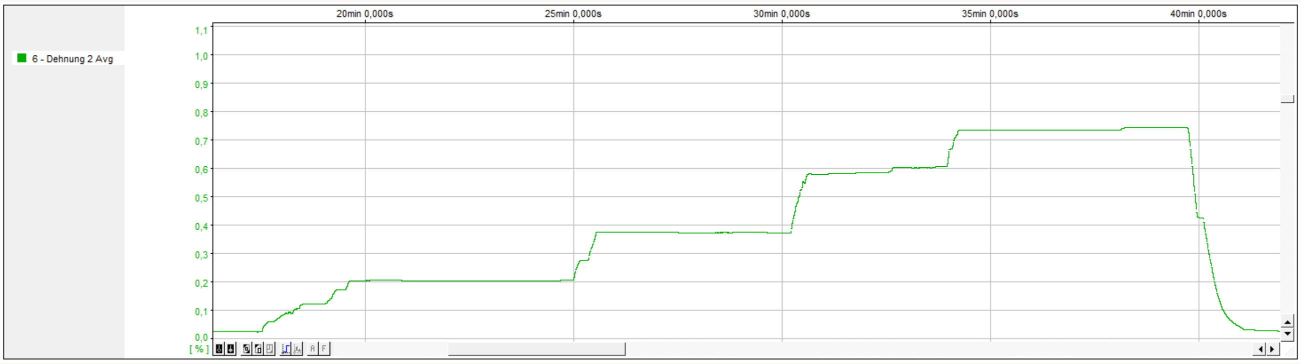


Requirement of DIN EN 60794-1-20 (4.2.1)

Min. value: 400 N / duration of 5 min or weight of 1 km cable (whichever is the higher value)

TS = Short-term load (fibre elongation) TL = Long-term load (fibre elongation, attenuation change)

Comparison 2: Cable elongation in relation to the tensile force applied TS (short-term) und TL (long-term) [N]



Requirement of:

E DIN EN 60794-2-20: none

E DIN EN 60794-1-21 / Method E1 3.4.1 e:

The attenuation change and/or fibre elongation must be recorded as a function of the tension on the cable or of the elongation.

Fibre elongation εF in relation to tensile load

Not tested. Supplier agreement, due to ambiguity in interpretation of the standard.

Requirement according to:

E DIN EN 60794-2-20 Abs. 4.2.1:	The allowable fibre elongation should be agreed on by client and supplier.
Note 1 in the standard:	It is inadvisable to subject the fibre to a tensile load that is more than 60% of the verification test load for glass fibres only.

Mechanical requirement according to E DIN EN 60794-2-20 (2002:04)

Tensile strength: Method IEC 60794-1-2, E1A and/or E1B

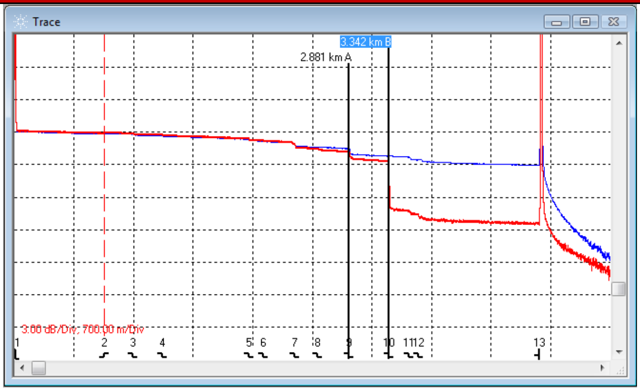
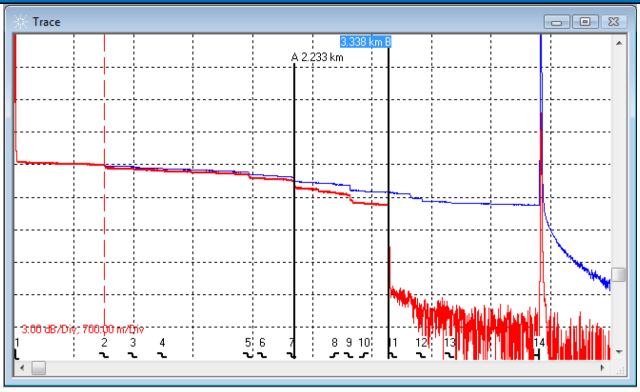
Requirement: Note: Fibre Optics considers compliance with this requirement to be unrealistic when testing longer lengths (50 or 100 m), on account of the extremely slow pulling speed.	Deflection device speed may be either 100 mm/min or 100 N/min.
Fibre Optics CT Method:	To determine attenuation change: ○ Gradual application of the load, keeping it constant for a duration of 5 m/min to 10 m/min. Installation speed 10 to 40 m/min.
Note:	
E DN EN 60794-1-21 (2011:05):	Method E1A and/or E1B
Procedures 3.4.2:	Application of the short-term (TS) and long-term (TL) loads (load maintained for 10 min)

Cable bending under tension according to E DIN EN 60794-1-21 (2011:05):

22.6 Details to be defined:	Highest tensile load to be exerted during the test (this is normally the highest load that can occur during cable-laying

Comparison 3: Tensile strength

Attenuation change Δα during and after testing at highest wavelengths 1550 nm ± 25 nm and 1625 nm ± 25 nm

2–point loss 1550 nm ±25 nm	2–point loss 1625 nm ±25 nm
	
058A-H.002 2.656 dB 058A-H.007 8.077 dB	058A-K.002 3.415 dB 058A-K.007 16.143 dB
Key: 002 = Reference value 50 N 007 = Removal of load after long-term TL load of 2000 N. Recovery time: 10 min	

Requirement:

DIN EN 60794-2-20 (Section 4.2.1)

- For method E1A there should be no attenuation change **after** the test
- There should be no visible damage to the cable elements

E DIN 60794-1-21 (Section 3.5)

- Attenuation change and fibre elongation in the sample should not exceed the values stated in the specification for the design type (IEC 60794 Part 3).

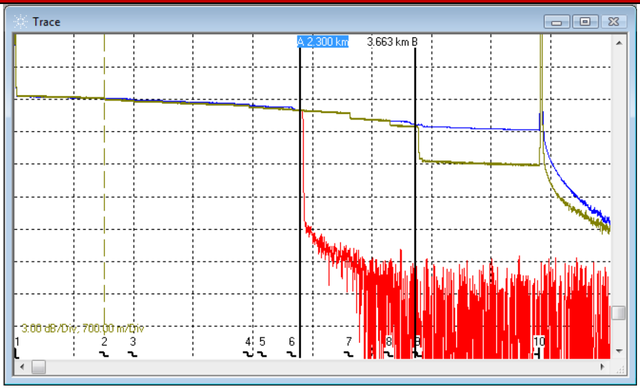
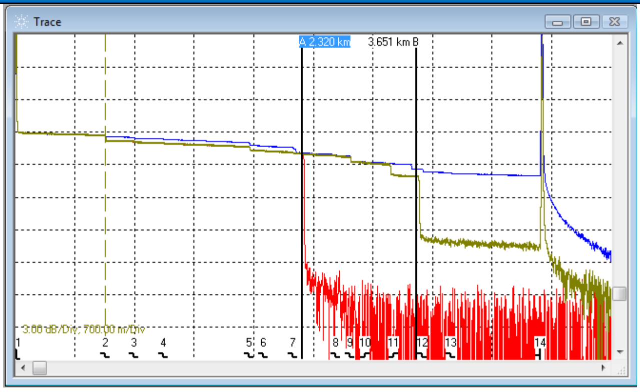
Test results:

- No attenuation change Δα during the TS (short-term) and TL (long-term) tests
- No irreversible attenuation change after the test
- No visible damage to the cable/ cable elements

No method has been defined for evaluating visible damage!

Comparison 4: Cable bending under load, "S-bend"

Attenuation change Δα during and after testing at highest wavelengths 1550 nm ± 25 nm and 1625 nm ± 25 nm

2–point loss 1550 nm $\pm$25 nm	2–point loss 1625 nm $\pm$25 nm
	
058A-H.002 2.656 dB 058A-H.014 22.521 dB 058A-H.017 5.954 dB	058A-K.002 3.415 dB 058A-K.014 16.241 dB 058A-K.017 9.673 dB
Key: 002 = Reference 50 N 014 = Removal of load after short-term TS load of 1000 N (2nd cycle) 017 = Removal of load after long-term TL load of 2000 N (1st cycle)	Requirement according to the standard = 1600 N

Requirement:

DIN EN 60794-2-20 (Abs. 4.2.10)

- For method E18 there should be no attenuation change after the test
- There should be no visible damage to the cable elements

E DIN 60794-1-21 (Section 22.5)

- On visual inspection without magnification the sample should show no sign of damage to the sheath and/or cable elements.
- If stipulated, there should be no irreversible attenuation change after the test exceeding the value stated in the specification for the design type.

Test results:

- Attenuation change Δα during the test

TS (short-term) min. value	at 1550 nm	$\leq$ 0.18 dB
Spec. 1600 N, actual 1000 N (2 cycles)	at 1625 nm	$\leq$ 0.19 dB
TL (long-term)		
Specified 2000 N (1 cycle)	at 1550 nm	$\leq$ 0.23 dB
	at 1625 nm	$\leq$ 0.64 dB

- Attenuation change Δα after removal of load < 22.5 dB
  (014) TS min. value, specified 1600 N, actual 1000 N (2 cycles)
  (017) TL specified value 2000 N, actual value < 2000 N
  (Recovery time approx.1.5 hours)

- After visual inspection without magnification, no damage to the sheath and/or cable elements
- Cable were very wavy
  The standard does not lay down any method of assessment.

Fibre Optics CT Fault analysis

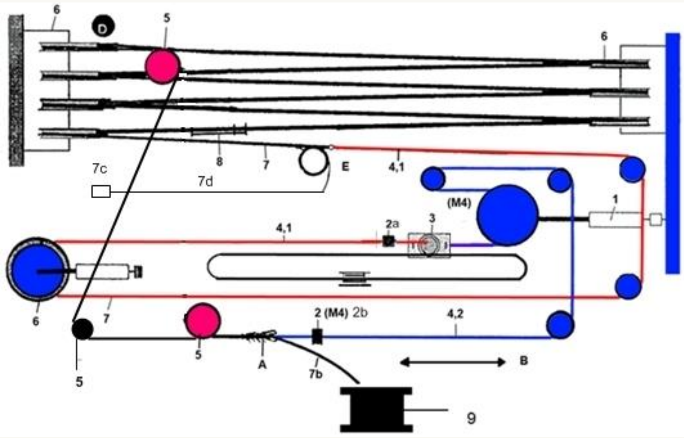
Attenuation change (in sudden increases) after removal of the tension (tests 3 & 4) and formation of waves in the cable after removal of tension in cable bending test

1. Fault analysis for the cable length subjected to tensile loading

In order to test the tensile strength of the cable and bending behaviour under load, a cable sample with an approximate length of 169 m was prepared in the testing place.

The sample length was divided up as follows for the FO combined tests:

- Cable length launching fibres No. 9 to A, no load: 37 m
- Cable length from A to E, under load: 113 m
- Cable length from E to 7c, no load: 19 m



1 Tensile force transducer
2 DMS device for measuring tensile force, with an error margin of < 3%
2a 20 kN measuring device
2b 5 kN measuring device
3 Dynamic pulling device, from 10 m at highest pulling tension for the optical cable/ velocity V= < 10 m/min, in pulling direction A ⇔ B
4 Auxiliary rope
5 Cablel/ deflection radius as stated in data sheet (standard)
6 Cable deflection rollers Ø 600 mm
7a Cable sample, length > 50/100 m, cable grip on both sides
7b Fibre fixed in position at pulling end
7c Fibre fixed in position at holding end
7d Special testing route
8 Device for measuring cable elongation
9 Cable drum with launching fibre
M4 PC for data entry (OTDR, tensile force, cable elongation)

Test specifications:

After a recovery period of approx. 24 hours, a length of approx. 85 m (measured from 7 c) was taken from the wavy part of the tensile-stressed cable sample and laid in a climate chamber. Here it was subjected to temperature cycling tests according to DIN EN 60794-1-2/F1, for the purposes of fault analysis.

TA +60°C high temperature/ 6 h and
TB -20°C low temperature / 6 h
4 cycles
Temperature change 1°C/ min

Test started after preparation an 85 m sample, following a recovery period of approx. 24 hours (i.e. 48 hours after the tensile load test).

Fig. 1

Test layout

Result:
Approx. 12 hours after the start of testing at temperature TA +60°C, a break similar to sudden increase in attenuation was recorded. (Fig. 2)

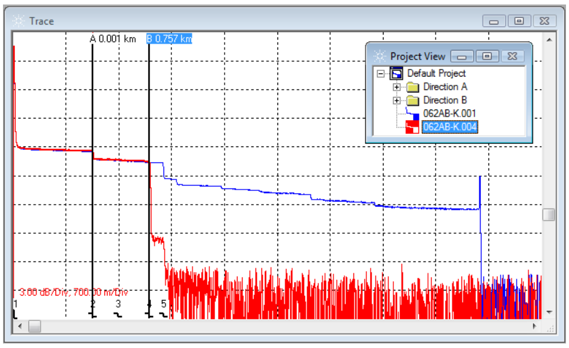


Fig. 2

5 days after completion of the temperature cycling tests, the fault was pinpointed using a source of red light. It was localised 76.5 m from the beginning of the cable (7b), about 3 m away from the cable deflection pulley 6 (Figs. 3 and.4), at a compression point in the optical multi-fibre splitter cable.

On taking a closer look to see whether this was due to a fibre break or a build-up of loops, the sudden increase in attenuation and the fibre loops had both disappeared.

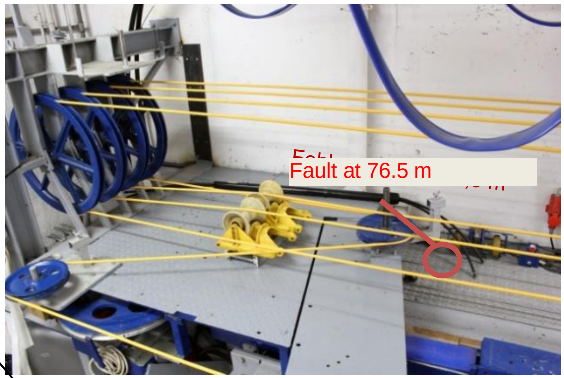


Fig. 3

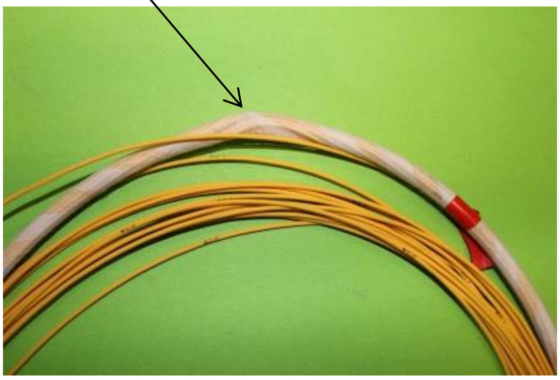
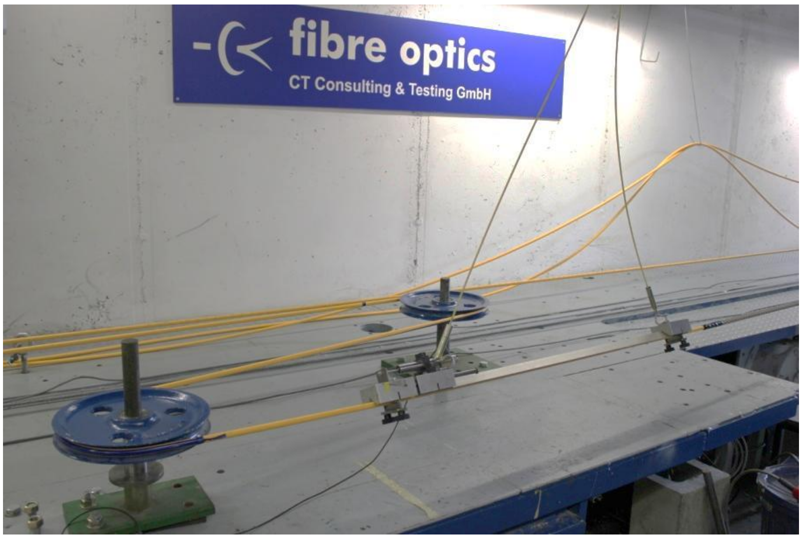


Fig. 4

2. Fault analysis on a new unstressed cable sample

To test the tensile strength of the cable and its bending behaviour under load, a new sample with a length of approx. 30 m was prepared in the testing place. The deflection radii were greater than for the first fault analysis.

Test: tensile strength according to DIN EN 60794-1-21 / E1A



Cable elongation in relation to tensile strength

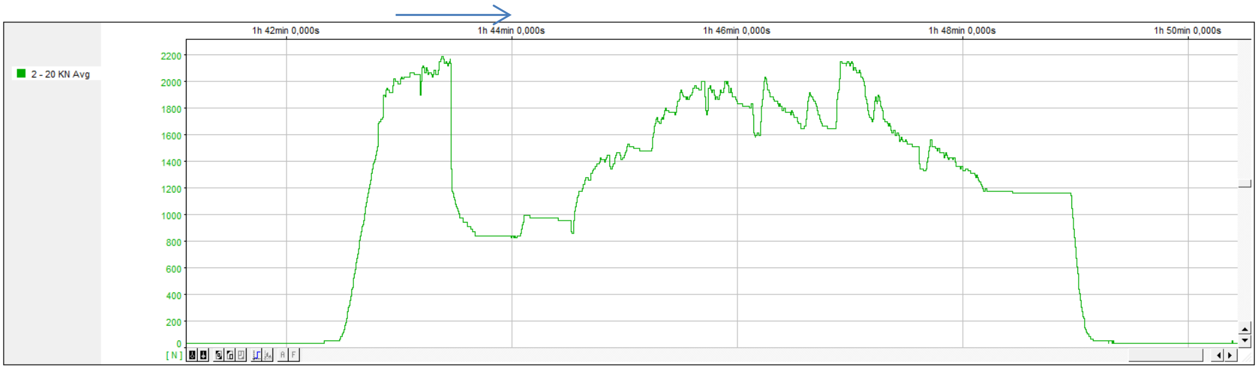
Requirement: No visible damage should be caused to the cable elements.

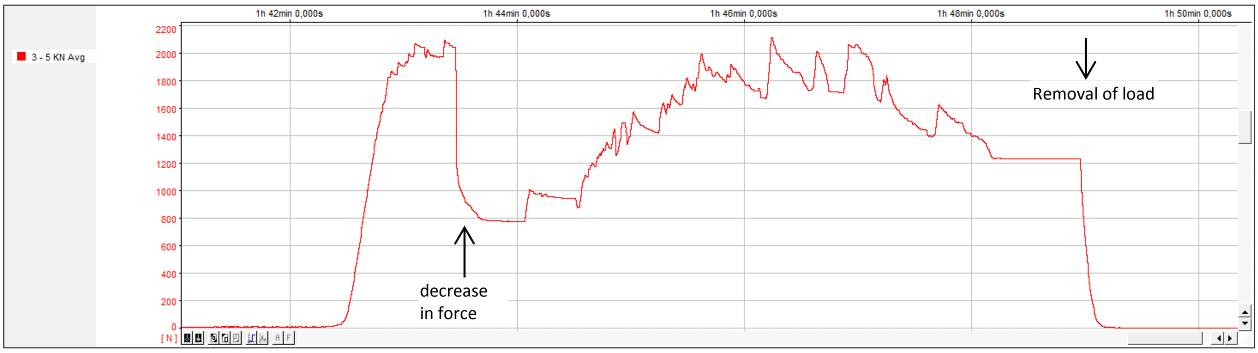
Test results:

- Reversible cable elongation ƐK
- No visible damage to the cable/ cable elements

Test: Cable bending under tension according to DIN EN 60794-2-20, Test procedure according to 60794-1-21 E18 (S-bend)

Deflection radius:	> 20 x cable diameter	
Tensile force:	TL min. load	1600 N = weight of 1 km cable
	TS short-term load	2000 N = ½ cycles: Pulling direction from A to B





Test results:

- Damage to the sheath and/or cable elements (but no assessment method exists)
- Sudden reduction in force can be seen (but no assessment method exists)
- According to the requirements of DIN EN 60794-2-20, 4.2.1, the test is passed.

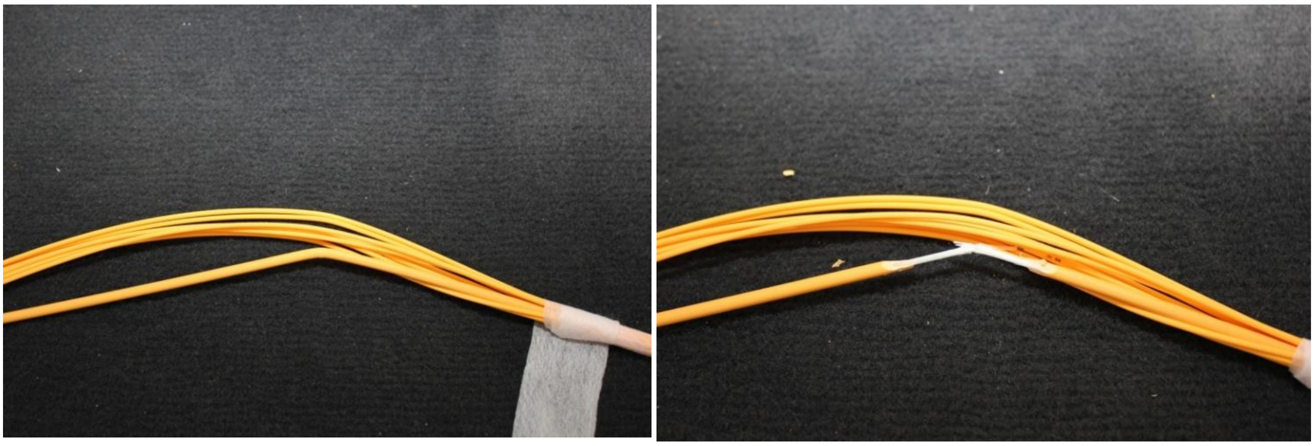
3. Fault analysis of jolting load reduction, cable bending under load

30 m of the cable sheath were removed for fault analysis.

Visual inspection (not magnified) revealed some damage to the fibre elements
Actual result: 2 FRP breaks

Break No. 1

Break No. 2



4. General construction values

Characteristic values of high-performance composites (FRP)

Tensile strength and tension/stretching performance under short-term load

The stability of a glass fibre rod depends on a variety of parameters. The main influences coming from the rod itself are: the glass content with its own stability, the process and quality of manufacture and the type and quality of resin and fibre coverings. The greatest external influences lie principally in the duration and level of stress (static and dynamic), the effect of reactive substances, temperature, lateral pressure and friction, for example at the deflection points of pre-stressing tendons.

As can be seen in Fig. 1, a linear stress-strain relationship (elastic behaviour) can be observed in the FRP up to loads of approximately 1000 N/mm². This was not surprising, as the glass fibres mainly involved in the load transfer are generally considered to be extremely elastic. The subsequent values showing a disproportional increase in elongation are probably due to incipient fibre breakage.

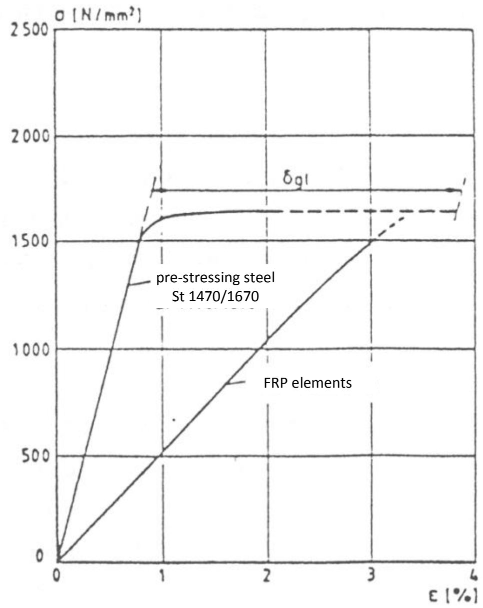


Fig. 1: Comparative stress-strain relationships of pre-stressing steel and FRP elements

The diagram also shows that there are considerable differences between the stress-strain behaviour of pre-stressing steel and that of FRP elements. The elastic modulus for FRP elements within this service load range is 51.000 N/mm², which is only 25% of the corresponding value for pre-stressing steel. This is of course an advantage with regard to the loss of elasticity caused by the shrinkage and creep of concrete, for example.

What is also noteworthy is the absence of an extended area of deformation before actual fibre breakage, which is present in the case of pre-stressing steel. This property of steel is useful as a warning that breakage is about to occur, but is compensated for in the glas fibre rods by the relatively high elasticity they still possess beyond the service load range.

Source: Institut für Bauwesen (Institute for Applied Mechanics), Stuttgart University

Outlook

Unfortunately, communication problems often arise between supplier and client regarding the quality that has been ordered, due to the fact that the standards can be interpreted in varying ways (see News 00/04).

News 00/05

Two further examples, for buried cables or cables in ducts according to DIN EN 60794-3, 60794-3-10:2002 and testing standard IEC 60794-1-21 (Draft May 2011), show that it is necessary for action to be taken. Fibre Optics holds semniars on these themes (see a typical invitation below).

Seminar
"Criteria for establishing the service life of an optical cable"

In a joint seminar by Fibre Optics CT GmbH and MTS Messtechnik Service Dipl.-Phys. K. Kimmich, Stuttgart, we demonstrate the relevant criteria for fibre property changes within the 20-year service life period. We do this in a practical way, on the basis of actual test results and by carrying out a tensile "cable bending under load" test together.

We will send you the following information on request, if you want to attend the seminar:

- News 00/05
- Agenda
- Info on the seminar "Criteria for establishing the service life of an optical cable"

Dates:	12th June 2013
	11th July 2013
Location:	Stuttgart
Cost:	675.00 Euro per person
No. of participants:	min. 4, max. 8

5. Summary

This FO 00/04 edition of the Fibre Optics' newsletter, with its request for readers' comments, is aimed at providing the client with an example of how to assess the quality of an optical cable and prepare a technical delivery specification for special requirements.

You as the client are the only one who can influence the quality of your cable regarding the problems listed here:

The first design fault "FRP Ø1.5 mm", causing FRP breakage in fault analyses Nos. 2 and 3.

The second design fault "stranding length and cable design", with the formation of loops in the fibres. Fault analysis No.1 and attenuation change after removal of the load in test No.4, page 7.

The third fault lies in the requirements laid down by standard E DIN EN 60794-2-20.
In section 4 of this standard (on tests), there is no stipulation that all tests must be carried out, and the frequency of testing is left to agreement between client and supplier.

Consequence: Tests not demanded by the client will not be carried out by the supplier!

Example 1: Cabled fibre overlength

Example 2: Fibre elongation 60794-1-2, /Method E1A / or E1B
For this cable, the allowable fibre elongation of ≤ 0.33% would already be exceeded at a tensile load of 500 N.

Example 3: Cable bending under tensile load 60794-1-2 or 60794-1-21 method E18
It was possible to reveal potential problems with objective evidence.

Contact

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