

Pretensioning of cables PFEIFER Cable Structures

Cable structures technology

Info Nr. 2

1-2011

PFEIFER
SEIL- UND HEBETECHNIK
GMBH

DR.-KARL-LENZ-STRASSE 66
D-87700 MEMMINGEN
TELEPHONE +49 (0) 83 31-937-393
TELEFAX +49 (0) 83 31-937-624
E-MAIL cablestructures@pfeifer.de
INTERNET www.pfeifer.info

Pretensioning of cables

This paper focuses on structural cables. Tension members of this kind are perfectly suitable for light-weight, filigree structures. They are the basis for a transparent, light and resource-efficient construction.

The term “tension members” stands for ready-made systems consisting of cables and rods. All PFEIFER tension members are technically approved.

- > PE cable tension members made of stainless steel open spiral strands: European technical approval ETA-11/0160
- > PG cable tension members made of open spiral strands and PV made of full locked cable with GALFAN galvanised wires: European technical approval ETA-11/0160
- > ZSS hot dip galvanised tension rod systems: European technical approval ETA-04/0039

With such a wide range of products and the ability to offer custom made parts, we focus on the needs of architects and structural engineers. The client receives ready-made and easy to install products. Nevertheless, these tension members require special attention. This is essential when the cables are used within a pretensioned system.

For structural analysis on more complex cable systems we recommend the use of an analysis that is designed for framework systems that is available on the market.

In the following, we would like to exemplify how to analyse a cable system with additional loads. This paper 1/2011 should serve as a useful document, complementing the literature generally available.

All information papers are available for download on the Internet under: <http://www.pfeifer.de/en/cable-structures/download/technical-info/>

We would also appreciate your suggestions for future information papers.



Determination of the cable forces using a measuring gauge for cable tension from PFEIFER Seil- und Hebeteknik GmbH

Pretensioning of cables

The formulas shown are only valid as long as all cables are under load!

A spiral strand PG 55 with two open swaged fittings of the type 980 is attached to the upper fixed point A. With the help of a hydraulic tensioning device, mounted at fixed point B, the cable is stretched until the lower open swaged fitting can be attached to point B. The cable is now pretensioned with the force F_V (figure 1).

Cable data (PFEIFER catalogue page 3/42):

Size	PG 55 (D = 24,4 mm)
Limit tension	326 kN
Metallic cable cross section	A = 347 mm ²
Module of elasticity	E = 160 kN/mm ²

a) Cable without additional load

In analogy to "Petersen Stahlbau" – (3rd edition) p. 518 / 519 the following applies:

The expression $(E * A) / L$ can be seen as the "modulus of resilience C" of the cable.

$$C = (E * A) / L \quad (1)$$

The cable elongation for a certain pretensioning force is calculated according to the formula:

$$\Delta L = F_V / C \quad (2)$$

Example 1

Cable length: L = 10 000 mm

Pretensioning force: $F_V = 100$ kN

$C = (E * A) / L = 5,55$ kN/mm corresponding to (1)

$\Delta L = F_V / C = 18$ mm corresponding to (2)

The cable is stretched by 18 mm under the pretensioning force.

This means, in order to reach a pretensioning force of 100 kN in the cable, the cable has to be produced 18 mm shorter (cable creep is not considered).

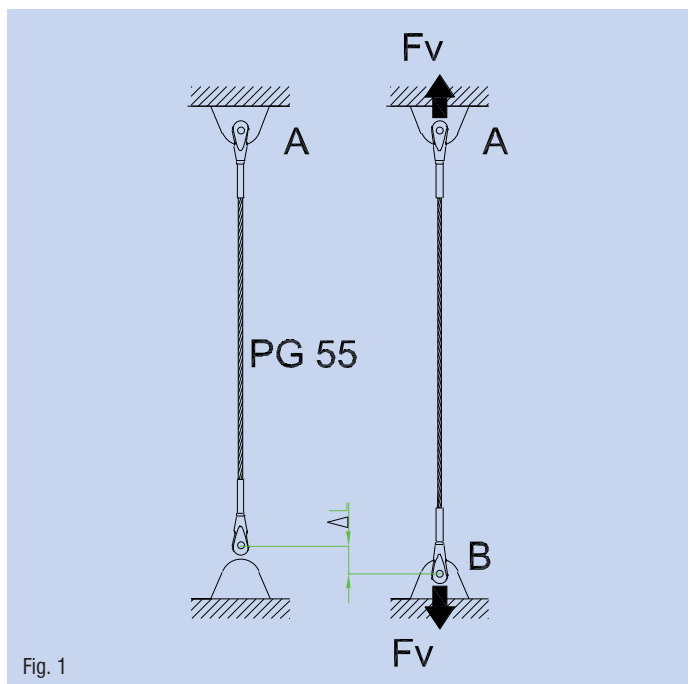


Fig. 1

b) Application of an additional load Z

Now an additional load Z is applied to the free cable length into the direction of the cable (figure 2). This can be accomplished e.g. by using a corresponding cable clamp. The cable is now notionally considered as a cable system. The upper section 'LT' functions as suspension cable, the lower section 'LS' functions as stabilizing cable.

Notations:

Suspension cable length:	LT
Stabilizing cable length:	LS
Module of elasticity suspension cable:	ET
Module of elasticity stabilizing cable:	ES
Met. cable cross section suspension cable	AT
Met. cable cross section stabilizing cable	AS
Additional load	Z

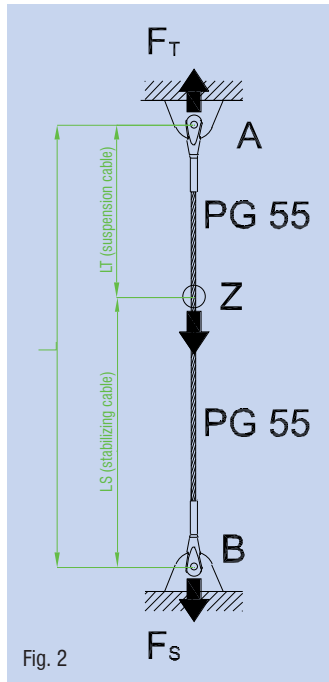


Fig. 2

"Spring constant" for suspension cable
$$C_T := \frac{E_T A_T}{L_T} \quad (3)$$

"Spring constant" for stabilizing cable:
$$C_S := \frac{E_S A_S}{L_S} \quad (4)$$

Elongation of suspension cable caused by FV:
$$\Delta L_T := \frac{F_V}{C_T} \quad (5)$$

Elongation of stabilizing cable caused by FV:
$$\Delta L_S := \frac{F_V}{C_S} \quad (6)$$

As long as the lower cable (stabilizing cable) is not slack, the following applies:

Force in the suspension cable:
$$F_T := F_V + Z \cdot \frac{\Delta L_S}{\Delta L_T + \Delta L_S} \quad (7)$$

Inserting (3 / 5) and (4 / 6) into (7) results in:

$$F_T := F_V + \frac{\frac{F_V L_S}{E_S A_S}}{\frac{F_V L_T}{E_T A_T} + \frac{F_V L_S}{E_S A_S}} \cdot Z \quad (8)$$

For $E_T \cdot A_T = E_S \cdot A_S$ (suspension cable and stabilizing cable are the same) we get by simplification:

$$F_T := \frac{(F_V L_T + F_V L_S + L_S Z)}{(L_T + L_S)} \quad (9)$$

Force in the stabilizing cable:
$$F_S = F_T - Z \quad (10)$$

Example 2a

Total cable length:	$L = 10\,000\text{ mm}$
Suspension cable length:	$L_T = 4000\text{ mm}$
Stabilizing cable length:	$L_S = L - L_T = 6000\text{ mm}$
Pretensioning force:	$F_V = 100\text{ kN}$
Additional force:	$Z = 50\text{ kN}$

Cable elongations caused by pretensioning force F_V (Z is not considered):

$$CT = (ET \cdot AT) / LT = 13.88\text{ kN/mm} \quad \text{corresponding to (3)}$$

$$CS = (ES \cdot AS) / LS = 9.25\text{ kN/mm} \quad \text{corresponding to (4)}$$

$$\Delta LT = F_V / CT = 7.2\text{ mm} \quad \text{corresponding to (5)}$$

$$\Delta LS = F_V / CS = 10.81\text{ mm} \quad \text{corresponding to (6)}$$

By pretensioning the cable from 0 up to 100 kN, the 4000 mm long "suspension cable" stretches by 7.2 mm and the 6000 mm long "stabilizing cable" stretches by 10.81 mm

By application of the force Z , the following new cable forces occur:

$$F_T := \frac{(F_V L_T + F_V L_S + L_S \cdot Z)}{(L_T + L_S)} = 130\text{ kN} \quad \text{corresponding to (9)}$$

In the suspension cable the force increases from 100 kN up to 130 kN

$$F_S = F_T - Z = 80\text{ kN} \quad \text{corresponding to (10)}$$

In the stabilizing cable the force decreases from 100 kN down to 80 kN

Example 2b (like example 2a, Z , however, applies further down)

Total cable length:	$L = 10\,000\text{ mm}$
Suspension cable length:	$L_T = 7000\text{ mm}$
Stabilizing cable length:	$L_S = L - L_T = 3000\text{ mm}$
Pretensioning force:	$F_V = 100\text{ kN}$
Additional force:	$Z = 50\text{ kN}$

Cable elongations caused by pretensioning force F_V (Z is not considered):

$$CT = (ET \cdot AT) / LT = 7.93\text{ kN/mm} \quad \text{corresponding to (3)}$$

$$CS = (ES \cdot AS) / LS = 18.51\text{ kN/mm} \quad \text{corresponding to (4)}$$

$$\Delta LT = F_V / CT = 12.61\text{ mm} \quad \text{corresponding to (5)}$$

$$\Delta LS = F_V / CS = 5.4\text{ mm} \quad \text{corresponding to (6)}$$

By pretensioning the cable from 0 up to 100 kN, the 7000 mm long "suspension cable" stretches by 12.61 mm and the 3000 mm long "stabilizing cable" stretches by 5.4 mm

By application of the force Z , the following new cable forces occur:

$$F_T := \frac{(F_V L_T + F_V L_S + L_S \cdot Z)}{(L_T + L_S)} = 115\text{ kN} \quad \text{corresponding to (9)}$$

In the suspension cable the force increases from 100 kN up to 115 kN

$$F_S = F_T - Z = 65\text{ kN} \quad \text{corresponding to (10)}$$

In the stabilizing cable the force decreases from 100 kN down to 65 kN

c) Different cables

Catenary cable and stabilizing cable consist of two separate cable pieces with different diameters (Figure 3).

Cable data (PFEIFER catalogue page 3 / 42):

	catenary cable	stabilizing cable
Size	PG 55 (D = 24.4 mm)	PG 25 (D = 17 mm)
Limit tension	326 kN	158 kN
Metallic cable cross section	A = 347 mm ²	A = 168 mm ²
Module of elasticity	E = 160 kN/mm ²	E = 160 kN/mm ²

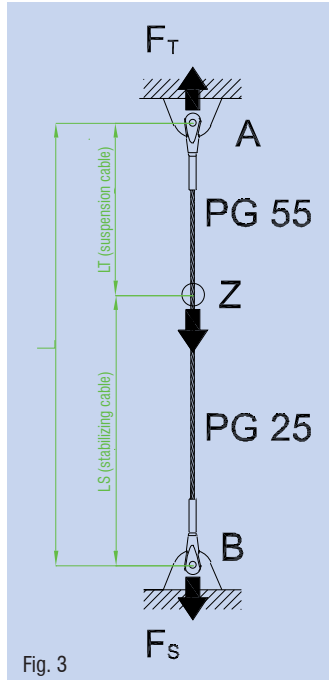


Fig. 3

Example 3 (like example 2a, however, suspension cable PG 55 and stabilizing cable PG 25)

Total cable length:	L = 10 000 mm
Suspension cable length:	LT = 4000 mm
Stabilizing cable length:	LS = L - LT = 6000 mm
Pretensioning force:	FV = 100 kN
Additional load:	Z = 50 kN

Cable elongations caused by pretensioning force FV (Z is not considered):

CT = (ET * AT) / LT = 13,88 kN/mm	corresponding to (3)
CS = (ES * AS) / LS = 4,48 kN/mm	corresponding to (4)
ΔLT = FV / CT = 7,2 mm	corresponding to (5)
ΔLS = FV / CS = 22,32 mm	corresponding to (6)

By pretensioning the cable from 0 up to 100 kN, the 4000 mm long "suspension cable" (PG55) stretches by 7.2 mm and the 6000 mm long "stabilizing cable" (PG25) stretches by 22.32 mm.

By application of the force Z, the following new cable forces occur:

$$F_T := F_V + \frac{\frac{F_V L_S}{E_S A_S}}{\frac{F_V L_T}{E_T A_T} + \frac{F_V L_S}{E_S A_S}} \cdot Z = 137,8 \text{ kN} \quad \text{corresponding to (8)}$$

In the suspension cable the force increases from 100 kN up to 137.8 kN

$$F_S = F_T - Z = 87,8 \text{ kN} \quad \text{corresponding to (10)}$$

In the stabilizing cable the force decreases from 100 kN down to 87.8 kN

PFEIFER

PFEIFER