Some remarks on the analytical treatment of prestressing

Autor(en): **Jennewein, Mattias**

Objekttyp: **Article**

Zeitschrift: **IABSE reports = Rapports AIPC = IVBH Berichte**

Band (Jahr): **62 (1991)**

PDF erstellt am: **23.07.2024**

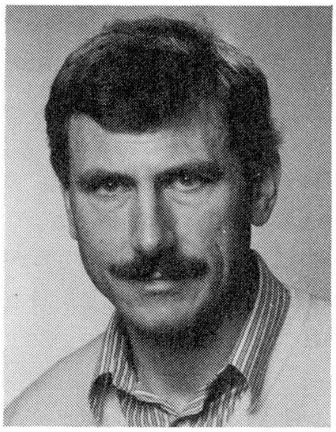
Persistenter Link: https://doi.org/10.5169/seals-47642

Some Remarks on the Analytical Treatment of Prestressing

Quelques remarques au sujet du traitement analytique de la précontrainte

Einige Bemerkungen zur analytischen Behandlung der Vorspannung

Mattias JENNEWEIN
Dr.-Ing.
Univ. of Stuttgart
Stuttgart, Germany



Mattias Jennewein, born 1948, studied at the University of Stuttgart, worked for five years in a consulting firm, for ten years at the Institute for Structural Design, University of Stuttgart and did there his doctorate on the design of structural concrete with strut-and-tie models.

SUMMARY

What is better: to handle prestressing as a self-strained condition or as a load? The answer to this question (shown by means of an example) is only obvious if prestressing is defined as the load which is produced by the hydraulic jack.

RÉSUMÉ

Vaut-il mieux considérer la précontrainte comme un état d'autocontrainte ou plutôt comme une charge? A l'aide d'un exemple, on montre qu'une réponse à ces questions peut être obtenue si l'on considére la précontrainte comme la charge produite par une presse hydraulique.

ZUSAMMENFASSUNG

Ist es besser, die Vorspannung als Eigenspannungszustand oder als Last zu behandeln? An einem Beispiel wird gezeigt, dass die Antworten auf alle Fragen nur einfach werden, wenn die Vorspannung als diejenige Last definiert wird, die mit der hydraulischen Presse erzeugt wird.

Some remarks on the possibilities to take "prestressing" into account in a beam with an unbonded cable (fig. 1) as an example.

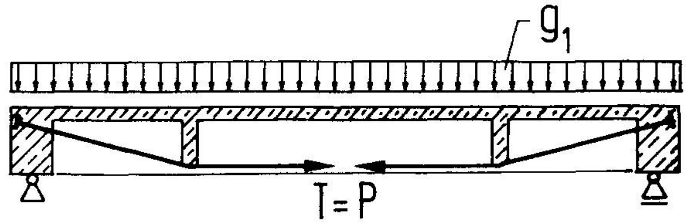


Fig. 1 Statically determinate structure during prestressing, loaded with P and g_1

During prestressing the structure is statically determinate, both internally and externally. The force T = P in the cable is determined only by prestressing. During prestressing the dead load g_1 acts as well. You can calculate all the stresses due to prestressing T = P and the load g_1. This is very simple, as you see.

However it is not simple at all if you look at it in the usual way, where prestressing is defined as the self strained condition, refering to the statically indeterminate structure after anchoring. To calculate the self strained condition, you must calculate the influence of the dead load g_1 separately in the statically indeterminate structure. You are only able to do so, if you give up the reality and if you imagine, that the load g_1 acts from the beginning (before prestressing) on the indeterminate structure. Then the force in the cable T_{g1} attributed to dead load g_1 is substracted from the real prestressing force P.

$$"P" = P - T_{g1}$$

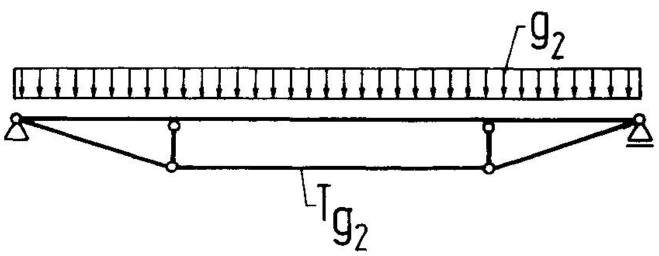
This reduced force "P" degenerates conceptually into an imaginary parameter called "prestressing" without any practical quality. The prestressing force "P" is not a fixed value any longer. Don't tell the man at the hydraulic jack this value, if you want a correct prestressing! This parameter depends on the load g_1. If the cable will be bonded, this parameter will even change its value from one section to the other. Furthermore it depends on time. Shrinkage and creep due to the stresses of "prestressing" and even due to the dead load reduce the self strained condition, that is to say the value of the parameter "prestressing". It is common use to speak then about "losses" of prestress.

If the structure leaves the uncracked state, you get into more trouble. What's then the meaning of "prestressing" as a self strained condition? There is no meaningful explanation! The superposition or the subdivision in independant loadcases and a self strained condition is no longer possible. Therefore the question, what does happen with the moment due to the prestressing, especially with the hyperstatic part of it in an externally indeterminate structure, and what does happen with the axial force due to prestressing, cannot be answered principally. It's pretty cold comfort to show, that the answer to that question is not very important with respect to the theory of plasticity. Equilibrium is still satisfied and compatibility is taken for granted on the "beautyfull" assumption that the materials are enough ductile.

As you can see now: the definition of prestressing as a self strained condition leads you to a complicate thinking, and you finish up a blind alley. It is able to lead you astray, if you want to have an answer on a question, which cannot be answered from this point of view. It is much simpler and furthermore generally valid to take facts as facts in their natural order. Let's start all over again.

During prestressing the structure in fig. 1 is statically determinate. The force T = P in the cable is nothing but exactly the force of prestressing P in theory as well as in practice. The man at the hydraulic jack is only told this value. During prestressing the dead load g_1 acts as well. You can calculate all the stresses due to prestressing T = P and the load g_1. You see, it is not at all necessary to know the self strained condition. By anchoring the cable, the statically determinate structure changes into an internally indeterminate one. Only the events which take place <u>after</u> anchoring as e.g. loading with additional dead loads or live loads and even shrinkage and creep act on that internally indeterminate structure and must be calculated accordingly for the actual stiffnesses of concrete, reinforcing and prestressing steel.

Any changes of stresses in the prestressing steel have to be added to its stresses due to the prestress P applied by the jack. For example, the loading with the additional dead load g_2 (fig. 2):



<u>Fig. 2</u> Internally statically indeterminate structure loaded with g_2

The total force in the cable is now composed of the prestressing force P and of the tie force T_{g2} due to the load g_2 and amounts to

$$T_{total} = P + T_{g2}.$$

If the concrete is cracked, the actual stiffness of the beam can be taken into account. Evidently this stiffness also depends on the stresses in the beam caused by the earlier loading g_1 and P.

What about shrinkage and creep? They do not reduce the prestressing force P, which is defined as the value applied by means of the hydraulic jack once forever. There are no losses of prestress! In reality shrinkage and creep only cause a redistribution of forces between concrete and steel as it also happens in a reinforced column (fig. 3).

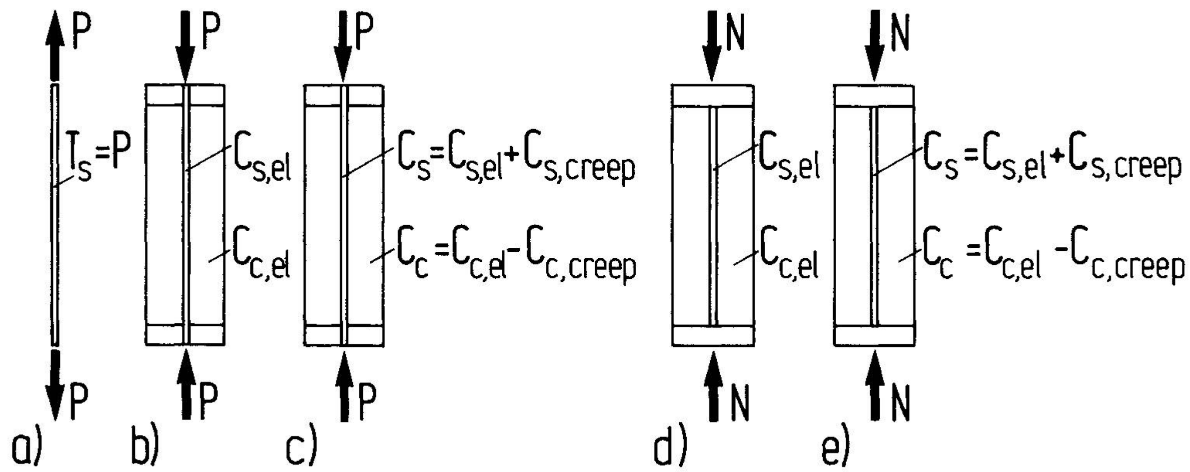


Fig. 3 a) Pretensioned steel member in the prestressing bed
b) and d) same elastic behaviour of a reinforced concrete member loaded by the prestressing force P and a column loaded by the axial force N
c) and e) same behaviour of the prestressed member and the column during creep

The steel member in fig. 3a shall be pretensioned in a prestressing bed with the prestressing force P. This prestressing force P acts as an external force on the reinforced concrete member (fig. 3b), reinforced with prestressing steel (fig. 3a) which therefore works like the steel in the column (fig. 3d). The compression force $C_{c,el}$ in the concrete and the compression force $C_{s,el}$ in the steel initially depend on the elastic stiffnesses of concrete and steel (fig. 3b and 3d).

$$C_{s,el} = P * (A_s*E_s) / (A_s*E_s + A_c*E_c) = P * n*A_s/A_i$$

$$C_{c,el} = P * (A_c*E_c) / (A_s*E_s + A_c*E_c) = P * A_c/A_i$$

Respectively in the column

$$C_{s,el} = N * (A_s*E_s) / (A_s*E_s + A_c*E_c) = N * n*A_s/A_i$$

$$C_{c,el} = N * (A_c*E_c) / (A_s*E_s + A_c*E_c) = N * A_c/A_i$$

When the concrete creeps, it reduces its stress at the expense of the steel, that is to say, the part $C_{c,creep}$ of the concrete force $C_{c,el}$ is transfered to the steel as a compression force $C_{s,creep}$. The total steel force therefore amounts to

$$T_{s,total} = P - C_{s,el} - C_{s,creep}.$$

This equation preserves all events according to their occurances in reality:

- the pretensioning of the steel,
- the application of the prestressing force onto the reinforced concrete member,
- the redistribution due to creep.

In the extreme case of unlimited creep the compression force C_c in the concrete decrease to zero and the compression force in the steel grows up to $C_s = P$ in the prestressed member (fig. 3c) respectively to $C_s = N$ in the column (fig. 3e). The total steel force then is in the prestressed member

$$T_{s,total} = P - P = 0.$$

This procedure can be applied to the creep problem of the beam in the example (fig. 1). When the concrete creeps in the internally indeterminate structure, the cable force T_{creep} comes into being due to redistribution (fig. 4a).

Fig. 4b shows the statically determinate structure loaded with all its loads, that is the dead load g_1 and g_2 and the force of the cable $T_s = P + T_{g2}$. The loading, which creates creep, depends itself on the earlier created redistribution forces due to creep. For simplicity it is only shown the first short time step $\Delta t = t_1 - t_0$ with $T_{creep} = 0$ as an initial condition. In any chosen statically determinate structure creep only results in displacements and not in any force. The deformations due to creep in every section can be assumed in proportion to the elastic deformations of the concrete under the influence of the loads in fig. 4b. The resulting displacement $\delta_{10} = \delta_{creep}$ of the cable due to creep (fig. 4c) is to be reversed by the cable force X_1 (fig. 4d), which is to be determined as ΔT_{creep}.

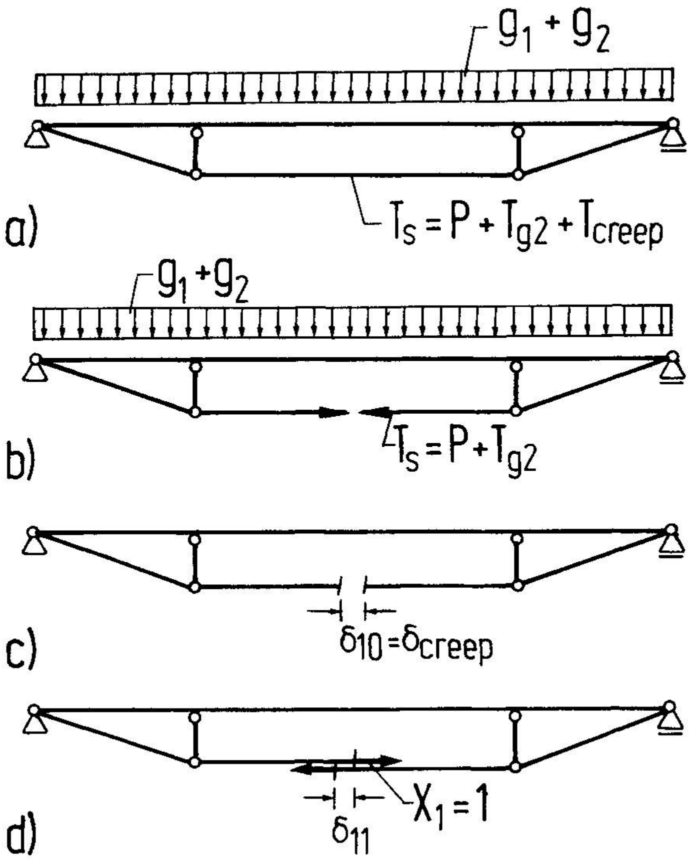


Fig. 4 a) When the concrete creeps, the tie force T_{creep} comes into being
b) the statically determinate structure and its loads
c) cable displacement $\delta_{10} = \delta_{creep}$ at the statically determinate structure, due to creep deformations
d) elastic displacement δ_{11} at the statically determinate structure due to $X_1 = 1$, considering the actual stiffness

The displacement δ_{11} of the cable due to $X_1 = 1$ depends on the actual stiffnesses, these are the stiffnesses under the influence of the loads in fig. 4b. All the internal forces of the structure due to ΔT_{creep} are redistribution forces. At the end of the first time step the total force in the cable amounts to

$$T_{total} = P + T_{g2} + \Delta T_{creep}.$$

You see, all things are kept tidy. The facts are not obscured,the relations between causes and their effects remain transparent. The procedure follows the facts and therefore it is generally valid.