Prestressed steel structures

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Prestressed Steel Structures

Constructions métalliques précontraintes

Vorgespannte Stahlbauten

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This paper introduces a special way of composing steel structures, in particular trusses, frames and Vierendeel beams; it results in considerable economy. This is obtained by reducing greatly the weight of steel required for the supporting structure, without any important amount of additional labor being introduced for the composition of this structure.

For trusses, the fundamental idea is the following: a bar AB with effective length l, cross-sectional area A and moment of inertia $I = A.r^2$ is able to resist the tensile force $N = A.s$ or the compressive force $R = A.s/w$ where s denotes the allowable axial stress for steel and w is a coefficient which depends upon the value of the slenderness ratio l/r. [1] For small values of the ratio l/r it is $w = 1$; then it is $N = R$. But for large values of the ratio l/r it is $w \gg 1$; then it is $R \ll N$; this means that the same bar resists a force which is much larger for tension than for compression. Therefore, in order to obtain the most economical solution for a truss, we try to make all long bars be acted upon by tensile forces, while compressive forces act only upon short bars. This is done in the following way:

We consider the fundamental isostatic supporting structure and make two independant sets of loads act upon it at the same time: I) dead and live loads, just as we do for any usual truss, and 2) prestress. The combination of these two sets of loads makes the compressive forces acting upon the long bars of the truss vanish or become unimportant. Of course considerable compressive forces act upon short bars.

For practical application we distinguish the following two cases:
Case I : To prestress the truss we displace the end-pins of it. This is clearly shown in Fig. I .
Case 2 : To prestress the truss we use additional bars as shown in Fig. 2

For frames and Vierendeel beams, the fundamental idea leading to the economical solution is the following: we make an additional set of artificial loads act upon the structure in such a way that it produces a state of stress opposite to the state of stress produced by dead and live loads. So these two states of stress produce a resultant state of stress which is much less important than either of them.

For the practical application of this technique the following condi-

Fig.I : STEEL TRUSSES PRESTRESSED THROUGH DISPLACEMENT OF END-PINS

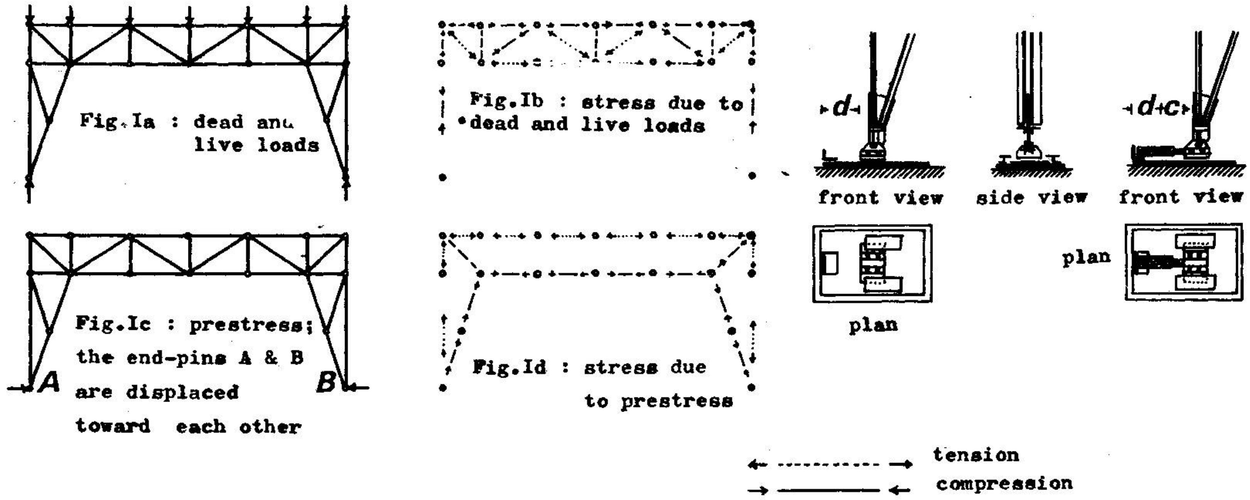
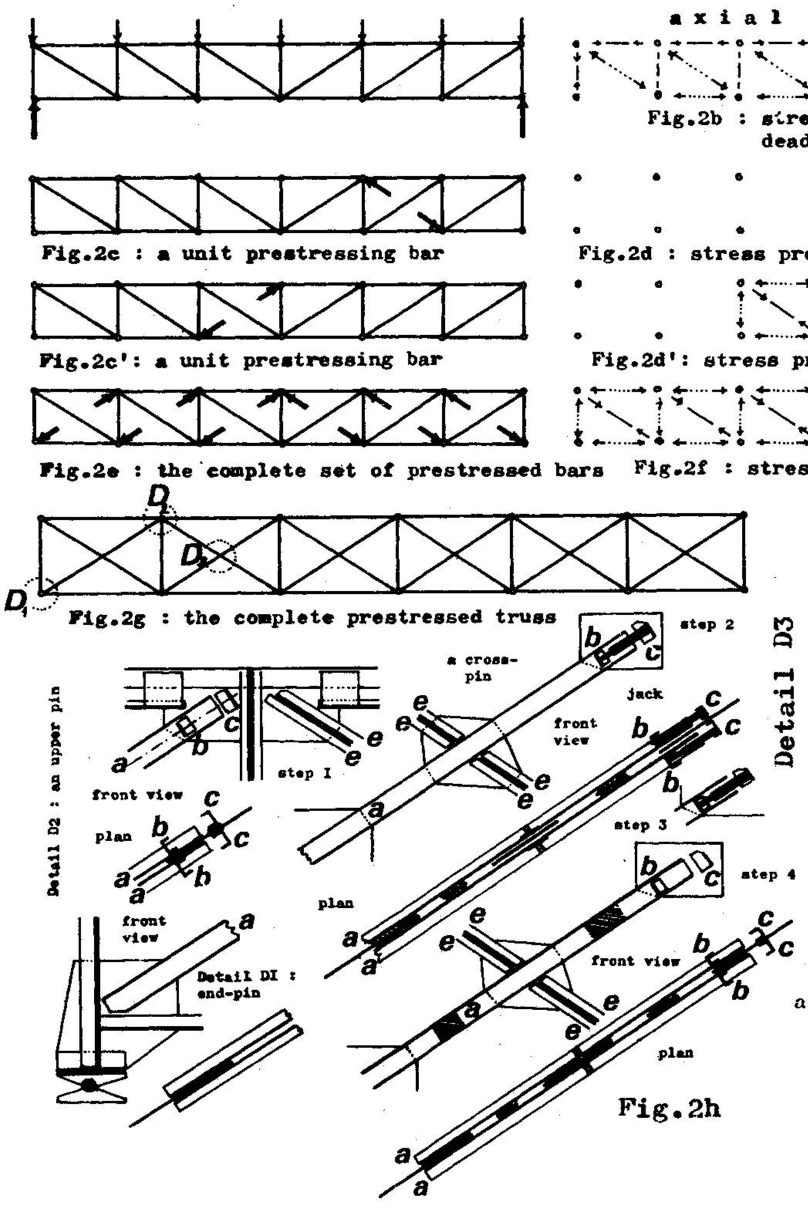
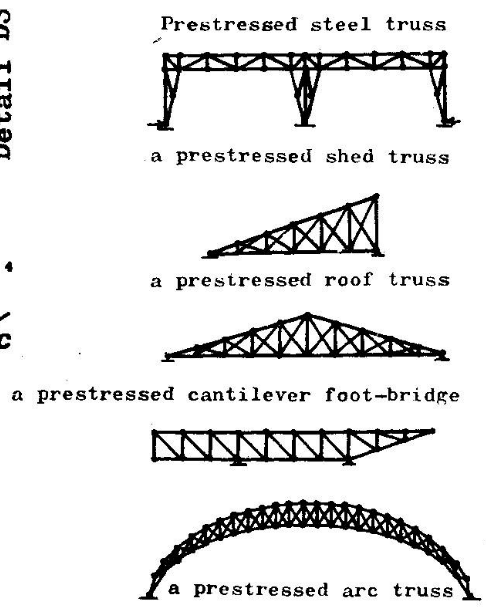


Fig.2 : STEEL TRUSSES PRESTRESSED BY ADDITIONAL BARS



EXAMPLES OF PRACTICAL APPLICATION



tion must be satisfied: a cheap way to produce the artificial loads,i.e. a cheap way to prestress the structure,must be available.This means that the device which we use to prestress the structure must require a small weight of steel and be easy to build.In the opposite case the resultant state of stress may well be much less important than either composant state of stress,but the cost for the production of the prestressing device proves higher than the cost for the construction of the usual structure.This is the reason why I have presently restricted this technique to the construction of frames and Vierendeel beams; prestress in these two kinds of structures costs practically nothing and is very easy to produce.This is done in the following way:

For frames,we use a jack to produce a horizontal displacement of the foot of the column of the complete frame.(See Fig.3 and Fig.4)

To prestress a Vierendeel beam we work in the following way: inner transverse stiffeners are cut at mid-points.The two pieces are fixed upon the lower and the higher girders in such a way that free ends at mid-points are displaced with respect to each other.A pair of horizontal forces are needed to bring these two free ends into coincidence.These forces produce considerable relieving bending moments that act upon the higher and the lower girder.So stress and strain produced in these girders by dead and live loads are greatly reduced.(See Fig. 5)

Fig.4 : STEEL FRAME PRESTRESSED THROUGH DISPLACEMENT OF THE COLUMN FEET

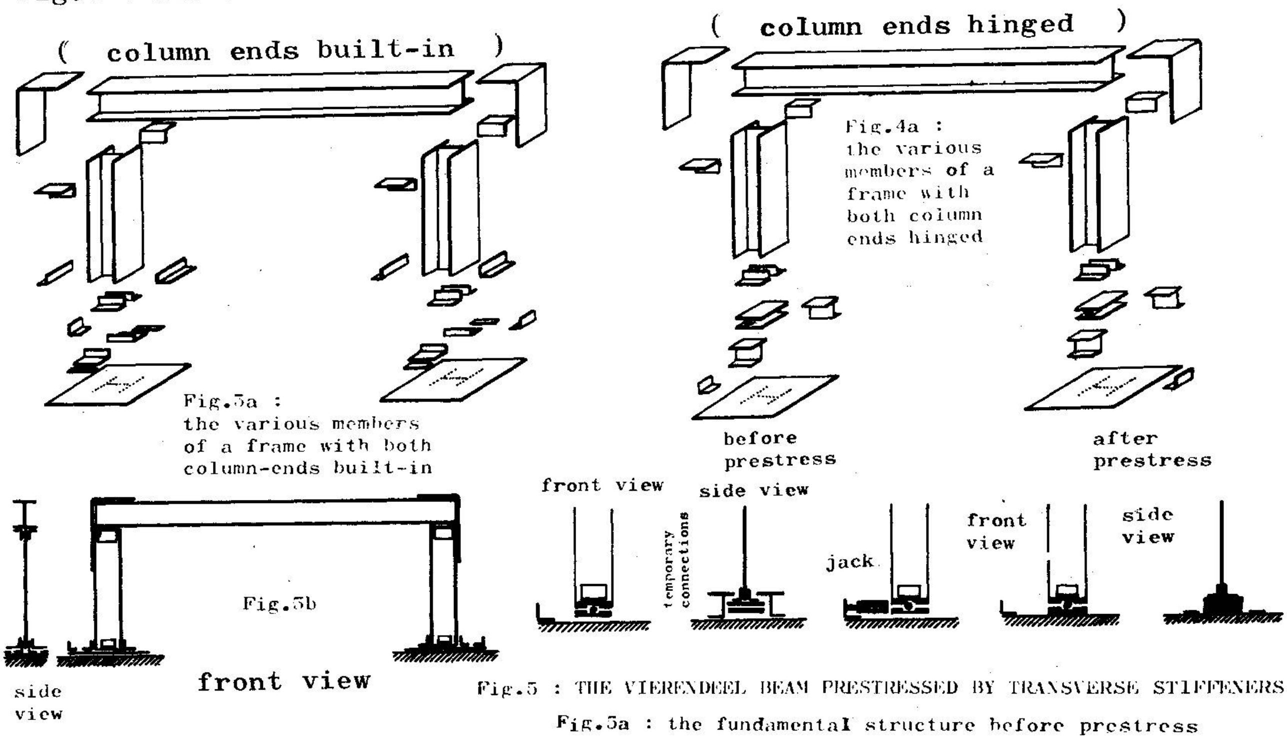


Fig.3a : the various members of a frame with both column-ends built-in

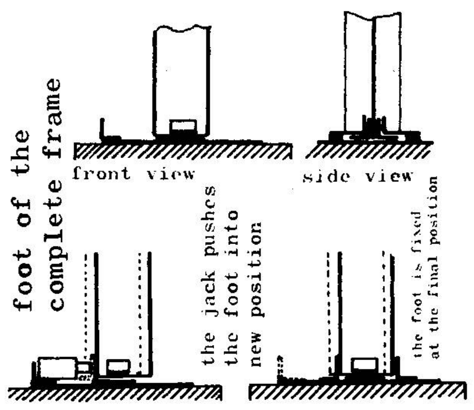
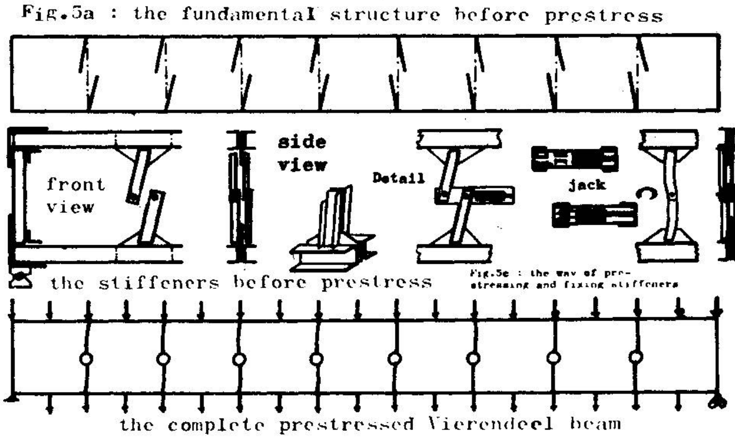


Fig.5 : THE VIERENDEEL BEAM PRESTRESSED BY TRANSVERSE STIFFENERS

Fig.5a : the fundamental structure before prestress



The determination of stress and strain produced in the structure by dead and live loads is done in the traditional way which is usual for such structures.[2] Attention is called upon the following point: for all loads acting upon the structure before prestress,stress and strain is determined for the fundamental structure; but for all loads acting after the prestressing bars and stiffeners have been incorporated into the complete structure,stress and strain is determined for the complete structure. It is equally so for the determination of stress and strain produced by the prestressing forces.We consider them as usual external loads.Every prestressing force is considered to act upon the structure that has already been built out of the fundamental structure a n d of all the prestressing bars or stiffeners that are already incorporated into the fundamental structure at the respective step of the procedure.Creep,in the way it effects computation of prestressed concrete works,is not taken into consideration, because it is generally admitted that creep in good steel is not important[3].

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SUMMARY

A new technique that reduces the weight of steel necessary for the construction of supporting steel structures is introduced. The fundamental idea is to prestress the steel structure in such a way that a state of stress opposite to the state of stress due to dead and live loads acting upon the structure is produced in it. Economy originates from the fact that the same steel bar is able to resist an axial force that is much larger for tension than for compression because of buckling.

RESUME

On présente une nouvelle technique de constructions métalliques, propre à réduire considérablement le poids de l'acier dans la construction. L'idée fondamentale est de produire une précontrainte de la construction métallique opposée aux sollicitations engendrées par le poids propre et les surcharges. L'économie provient du fait que la même barre métallique résiste à une force axiale de traction bien plus grande qu'à une force axiale de compression, à cause du flambement.

ZUSAMMENFASSUNG

Die Stahlbauten sind vorgespannt. Die Vorspannung reduziert das Gewicht des für die Stahlkonstruktion benötigten Stahls. Der Grundgedanke der Vorspannung ist, den Stahl vor der Belastung überall dort unter Zug zu setzen, wo die Belastung Druckspannungen erzeugt, so dass auf der Druckseite erst diese Zugvorspannungen abgebaut werden müssen, bevor tatsächlich Druck im Stahl auftritt.