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Prestressed Composite Hybrid Beams

Barres hybridés précontraintes et mixtes

Vorgespannte Verbund-Hybrid-Balken

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1. Introduction

In modern construction systems use is increasingly made of prestressing techniques with the scope to improve internal stress distribution even in the most severe operating conditions. Thus an internal bending stress can be obtained, as in the Preflex system [1], by bending Fe52 steel milled girders, with symmetrical section about the direction of bending, to form a composite concrete slab. The steel girder is submitted by external forces to a bending moment before in-situ casting of the concrete slab on the stretched flange. After curing, the externally applied stresses are relieved and the steel girder upon returning to its original conditions, causes the compression of the concrete slab.

It is thus possible to reduce the deformability of the beams and to increase operating stresses in the steel structure up to the maximum values permitted by tensile strength of the steel.

Furthermore, the oscillation of tensile stresses due to the application of load values variable in time is also reduced to the evident advantage of the endurance strength.

Finally, the concrete of the slab covering the stressed beam edge also gives fire protection.

Utilization of Fe52 steel involves, however, a rather reduced stress limit during the preliminary flexure of the girders.

Instantaneous deformation of the prestressed concrete and its subsequent increment due to creep phenomena are significantly reducing the preliminary flexure stresses. This means that the tensile strains in the concrete when submitted to the working load, may increase thus reducing the benefits obtained from the induced stresses.

Therefore we are of opinion that it would be very interesting to adopt, instead of Fe52 milled beam, a composite dissymmetric welded hybrid beam [2], [3] with a high yield strength flange component, such as for instance T1 steel.

The Fe52/T1 yield strength ratio is about 0.5. This means that the elastic strain of the T1 flange component during the preliminary flexure stage will be twice as great.

The loss of tensile strength due to instantaneous compression in the concrete and in particular as a result of creep will have a lower influence rate.

2. Calculation hypothesis and findings

The internal bending stress in prestressed girders can be considered as the sum of the effects due to the preliminary bending loads applied to the steel girders and to a second load system of the same magnitude but of opposite sign. These loads are applied on the composite beam after casting and curing of the concrete slab. When indicating by s and i the two flange components, the absolute stress values found in the steel and in the concrete are obtained by the relations:

$$\begin{aligned}\frac{\sigma_s''}{\sigma_s} &= 1 - \frac{w_s}{w_s'} ; \\ \frac{\sigma_i''}{\sigma_s} &= \frac{\sigma_i}{\sigma_s} - \frac{\sigma_i'}{\sigma_s} = \frac{w_s}{w_i} - \frac{w_s'}{w_i} \cdot \frac{w_s}{w_s'} ; \\ \frac{\sigma_c'}{\sigma_s} &= \frac{\sigma_i'}{\sigma_s} \cdot \frac{1}{n} = \frac{w_s'}{w_i} \cdot \frac{w_s}{w_s'} \cdot \frac{1}{n}\end{aligned}\quad (1)$$

In (1) letters without apex evidence the stresses during the preliminary flexure stage, discharge tension being indicated by one apex and final strains by two. W indicates the moment of resistance with regard to the Y axis.

Stresses have been calculated [4], [5] with reference to Fig. 1 taking into consideration the beam section consisting in 4 areas, with disregard of their centroid axis moment of inertia with reference to their displacement moment.

The distance between the two flange components is assumed to be equal to the height of the girder with a very slight excess error but nearly always compensated by disregarded moment of inertia of the web, to their centroid axis.

The classical Preflex girder type is characterized by:

$$\rho = 1 \quad \text{and} \quad w_s = w_i$$

The hybrid girder as proposed by us is characterized by a $\rho < 1$ ratio to be calculated provided that the two flange components are reaching contemporaneously their yield point during the preliminary flexure of the bare (uncoated) girder.

Therefore we'll find that:

$$\frac{w_i}{w_s} = \frac{2\rho + c_1}{2 + c_1} = \eta \quad (2)$$

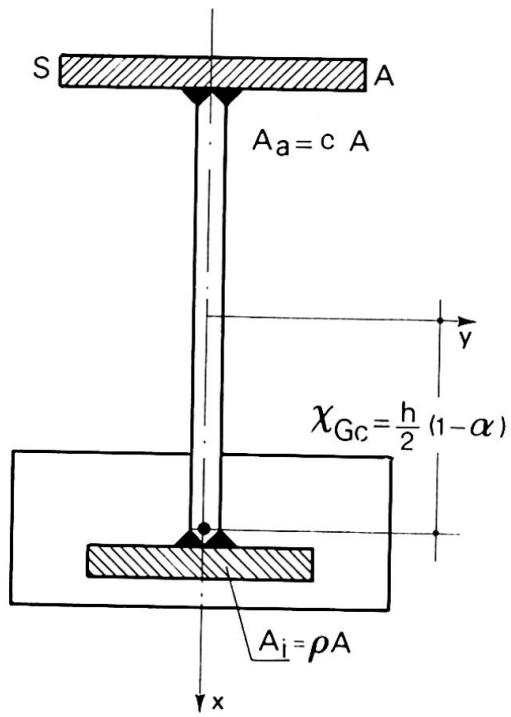


Fig. 1

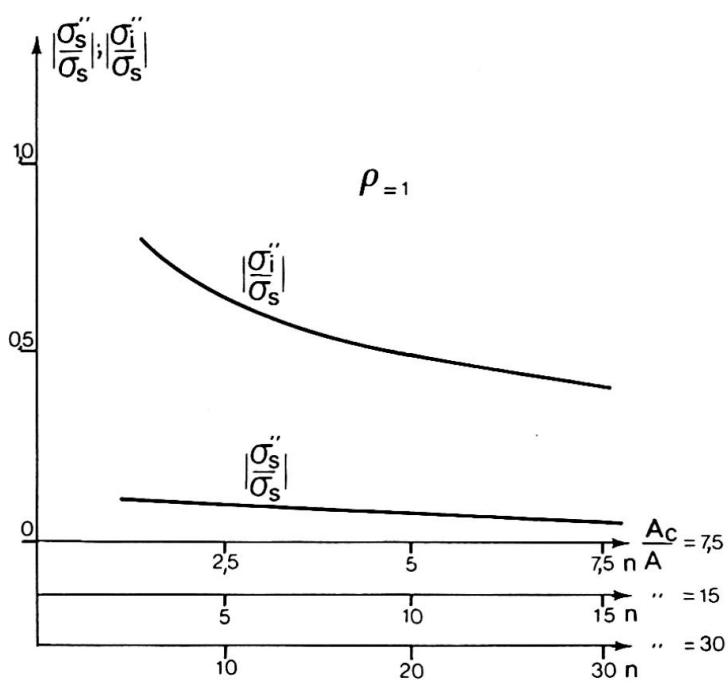


Fig. 2

Figures n° 2 and n° 3 show the relationship $\frac{\sigma_i''}{\sigma_s}$, $\frac{\sigma_s''}{\sigma_s}$ calculated based upon $\rho = 1$, i.e. for a Preflex type girder and $\rho = 0.325$ obtained from (2) for a hybrid beam assuming $c = 1$ for both girders.

Based upon the third equation of (1) and on the figures it will also be possible to calculate the stresses in the concrete.

At equal maximum stresses in the concrete, the hybrid beam will require slightly higher $\frac{A_c}{A}$ ratios.

In the cases here illustrated at limited concrete stress values, $\sigma_c = 250$ Kg/cm² the following values have been found:

$$\rho = 1 ; \frac{A_c}{A} = 15$$

$$\rho = 0.325 ; \frac{A_c}{A} = 17$$

Creep in the concrete reduces the stresses in the stretched flange components.

Fig. 4 shows the reduction between $t = 0$ and $t = \infty$, assuming an initial value for $n = 5$ and a final value $n = 15$. It is thus evidenced that the hybrid beam stretched flange always maintains a proportionally higher tensile strength.

η being the ratio between the yield stress values ≤ 1 .

The coefficient c_1 is connected with the geometric coefficient c (see Fig. 1) of the relation:

$$c_1 = \sqrt{\eta} \cdot c \quad (3)$$

c_1 has been found to be lower than c due to the plastic deformation of the web in vicinity of the stretched flange.

Evidently (1) are functions of n and are therefore time functions. When using Fe52 and T1 steel in the lower flange, $\eta = 0.5$ and $\frac{W_s}{W_i} = 2$ according to (2).

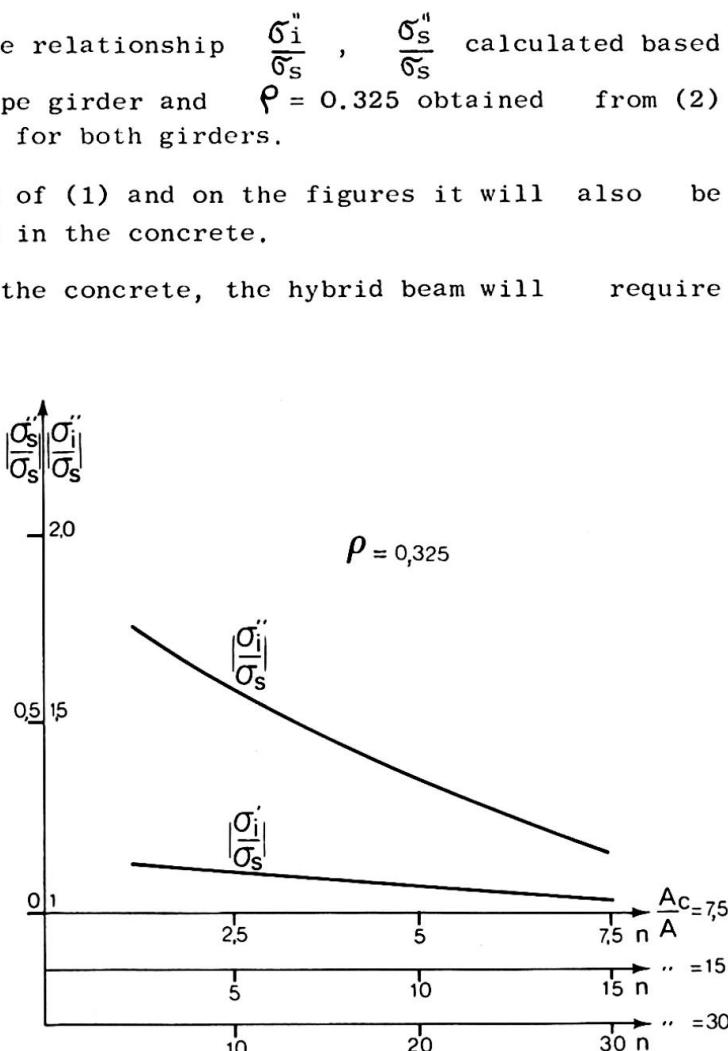


Fig. 3

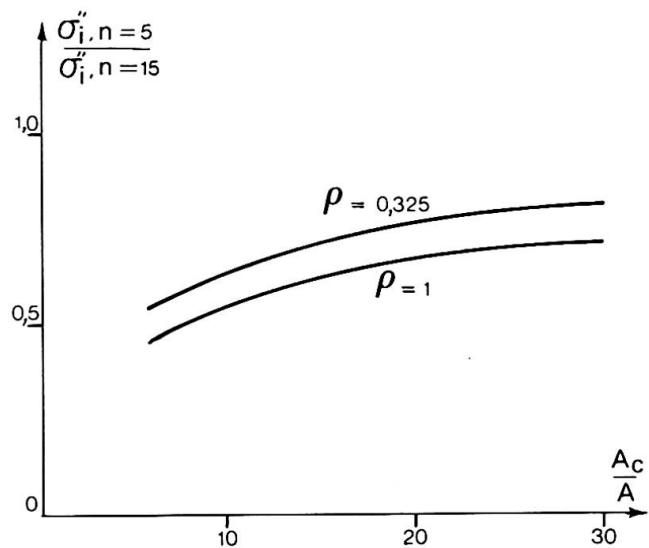


Fig. 4

3. Conclusions

The application of high tensile strength steel only for the stretched flange components and even at a reduced flange size, makes it possible to achieve higher precompression strength than can be obtained in a corresponding symmetrical girder.

This gives the possibility to use T1 steel to its maximum permissible tensile structural stress. Because of the slighter reduction due to prestressing, it will thus be possible to take complete advantage of the reduced tensile stress range in presence of variable loads.

Welding should permit plastic adaptation of less than 0.2% during the preliminary bending [6].

Welding costs can be at least partially offset by the possibility to obtain a counterflexure without particular operations, in addition of course to a greater range of applicable sections.

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SUMMARY

The authors have calculated the internal stress distribution achieved by bending of a steel beam, before casting a concrete slab on the stretched flange.

A comparison is also made between the behaviour of a Fe52 milled beam and the behaviour of a Fe52 and T1 hybride welded beam. The greater stresses and strains allowable for the T1 steel permit a better prestressing of the concrete.

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