

# On structural behaviour of hybrid I-beams

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### On Structural Behaviour of Hybrid I-Beams

Sur le comportement à la ruine des poutres en I hybrides

Zum Tragverhalten hybrider I-Balken

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This contribution refers to Theme Va of the Introductory and Preliminary Reports. It represents certain proposal for the plastic analysis of hybrid I-beams assuming combined action of bending and shear.

Author's treatment of mentioned problem bases upon that suggested by Strel'bitskaya for homogeneous beams /1/. Simultaneously Schilling's optimum design criteria are taken into account /2/. Collapse loads determined are compared with those resulting from the ASCE-AASHO regulations /3/.

Plastic bending-shear interaction analysis of homogeneous I-beams bases generally on the yield condition

$$\sigma^2 + 3\tau^2 = \sigma_0^2, \quad (1)$$

where  $\sigma$ ,  $\tau$  are the elastic bending and shear stresses, respectively, and  $\sigma_0$  is the yield stress. According to /1/ the elastic stress patterns are as shown in Fig. 1; both of them are more ( $\sigma$ ) or less ( $\tau$ ) inaccurate but fulfil the yield condition (1) at each point of the I-section and develop sufficiently exact (conservative) collapse load values. Similar analysis of hybrid I-beams can be based on stress patterns as given in Fig. 2.

With the specifications of Fig. 2 the fully plastic moment and shear,  $M_0$  and  $Q_0$  respectively, can be expressed as follows:

$$M_0 = \sigma_0 \frac{Afh}{2} + \alpha \sigma_0 \frac{th^2}{4} = \sigma_0 \frac{th^2}{4} (1+\alpha), \quad (2)$$

$$Q_0 = \alpha \sigma_0 th = \sigma_0 \frac{th}{\sqrt{3}} \alpha, \quad (3)$$

whereby the following numerical values of  $\alpha$  and  $\sigma_0$  are being considered:

- $\alpha = 1.00$ , for  $\sigma_0 = 36,000$  psi (homogeneous beam),
- $\alpha = 0.72$ , for  $\sigma_0 = 50,000$  psi
- $\alpha = 0.36$ , for  $\sigma_0 = 100,000$  psi (hybrid beams).

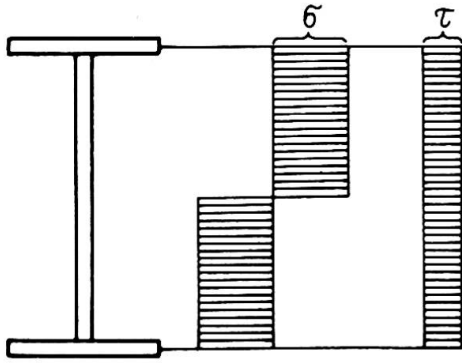


Fig. 1. Elastic stress patterns for homogeneous I-beam; assumed in [1]

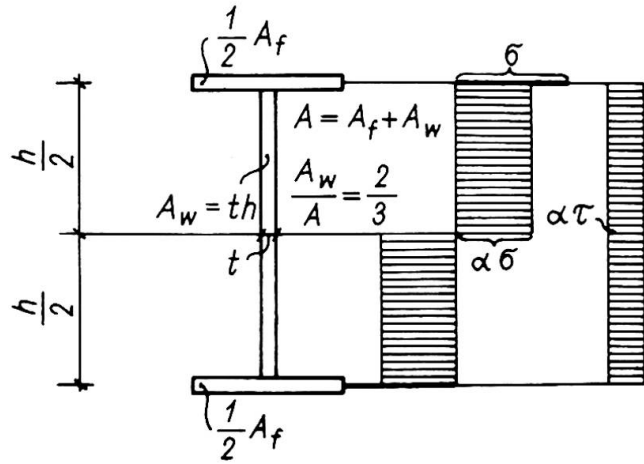


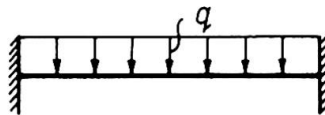
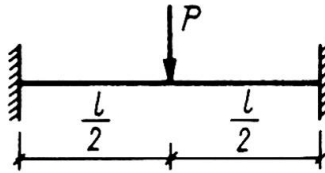
Fig. 2. Elastic stress patterns for hybrid I-beam; Author's assumption

Investigations performed concern in particular the beam fixed at both ends carrying single load  $P$  at span-mid or uniform load  $q$  all over the span (Fig. 3).

According to Author

$$P = \frac{8 \frac{M_o}{l}}{\sqrt{\frac{16 M_o^2}{l^2 Q_o^2} + 1}} = \frac{8 \frac{M_{ou}}{l}}{\sqrt{12 \left(\frac{h}{l}\right)^2 + \left(\frac{2\alpha}{1+\alpha}\right)^2}}$$

$$q = \frac{16 \frac{M_o}{l^2}}{\frac{16 M_o^2}{l^2 Q_o^2} + 1} = \frac{16 \frac{M_{qu}}{l^2}}{6 \left(\frac{h}{l}\right)^2 \frac{1+\alpha}{\alpha} + \frac{2\alpha}{1+\alpha}}$$



According to ASCE-AASHO

$$P = \frac{16 \frac{M_o}{l}}{\sqrt{\frac{64 M_o^2}{l^2 Q_o^2} \frac{\alpha}{1+\alpha} + 1 + 1}} = \frac{8 \frac{1+\alpha}{\alpha} \frac{M_{ou}}{l}}{\sqrt{12 \left(\frac{h}{l}\right)^2 \frac{1+\alpha}{\alpha} + 1 + 1}}$$

$$q = \frac{32 \frac{M_o}{l^2}}{\sqrt{\frac{128 M_o^2}{l^2 Q_o^2} \frac{\alpha}{1+\alpha} + 1 + 1}} = \frac{16 \frac{1+\alpha}{\alpha} \frac{M_{qu}}{l^2}}{\sqrt{24 \left(\frac{h}{l}\right)^2 \frac{1+\alpha}{\alpha} + 1 + 1}}$$

Fig. 3. General expressions of collapse loads

Extending the interaction formula of /1/

$$\frac{M^2}{M_o^2} + \frac{Q^2}{Q_o^2} = 1 \tag{4}$$

over to hybrid I-beams and taking into account the corresponding equation

$$\frac{M}{M_o} + \frac{Q^2}{Q_o^2} \frac{\alpha}{1+\alpha} = 1$$

resulting from ASCE-AASHO regulations /3/ a set of general collapse load expressions can be obtained which is given in Fig. 3;

therein

$$M_o = \frac{1+\alpha}{2\alpha} M_{ou} \tag{5}$$

where  $M_{ou} \equiv M_o (\alpha=1)$  holds for homogeneous (uniform) beam.

On the basis of the expressions derived the corresponding interaction curves, in terms of  $Pl/M_{ou}$  and  $ql^2/M_{ou}$  respectively, as functions of the span-depth ratio  $l/h$  can be found; this is illustrated in Fig. 4 and Fig. 5.

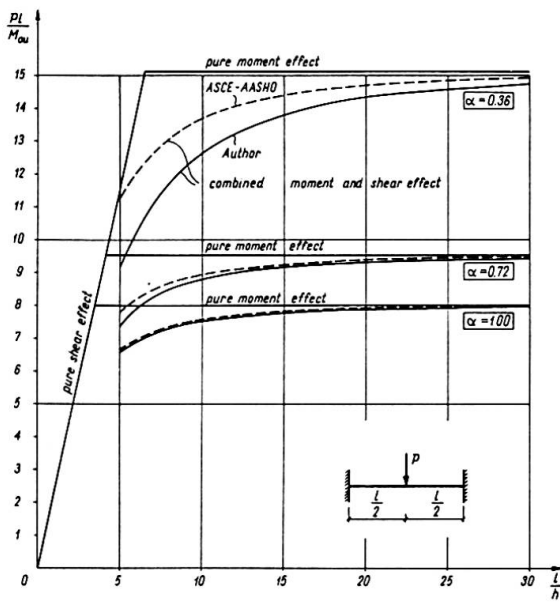


Fig 4 Collapse loads - concentrated

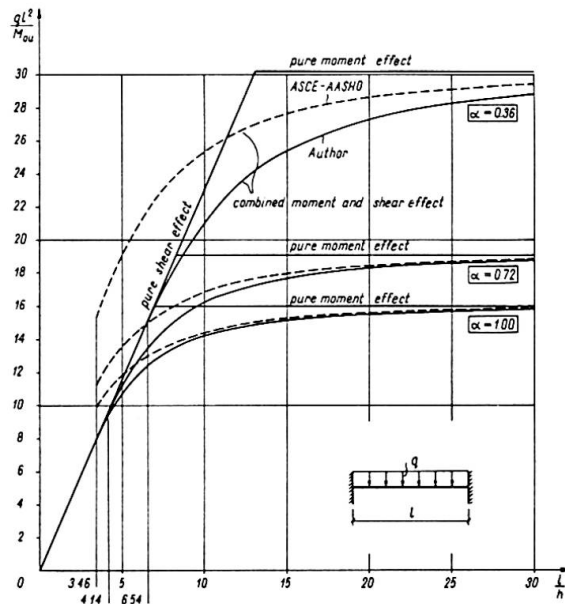


Fig 5 Collapse loads - uniform

In conclusion Author's proposal can be characterized as follows:

1. It yields collapse loads close (conservative) to those of the ASCE-AASHO regulations whereby the relative difference increases with a decrease of the  $l/h$ -ratio and the  $\alpha$ -value.
2. It visualizes clearly the dominating effect of pure shear for small  $l/h$ -ratios.
3. It can be found handy analysing non-uniform plastic torsion problems (bimoment - flexural-torsional moment interaction, St.-Venant torsional moment effect) of hybrid sections, as shown for the homogeneous ones in /1/ and /4/.

#### References

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- /4/ Strel'bitskaya, A.I.: Limit state of frames out of thin-walled members in bending with torsion (in Russian). Izdatel'stvo AN USSR, Kiev 1964.

#### SUMMARY

Simplified procedure is used to determine the ultimate load of hybrid I-beams in combined bending with shear. It has been found sufficiently exact and is recommended for analysis of similar problems within the theory of non-uniform torsion.

#### RESUME

Pour la détermination de la charge ultime de poutres hybrides en I soumises à la flexion et au cisaillement, on applique une méthode simplifiée. Celle-ci a donné des résultats suffisamment précis et est recommandée pour la résolution des problèmes similaires dans la théorie de torsion non uniforme.

#### ZUSAMMENFASSUNG

Ein vereinfachtes Verfahren wurde benutzt, um die Traglast hybrider I-Balken bei zusammengesetzter Biegung mit Schub zu bestimmen. Dieses wurde ausreichend genau gefunden und wird zur Behandlung benachbarter Probleme innerhalb der Theorie der Wölbkrafttorsion empfohlen.