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The design of the webplates of light alloy plate girders

Reply to the discussion

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Réponse à la discussion

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Dr. Rockey thanks Professor Massonnet for his kind remarks and for presenting his valuable communication.

The author is particularly glad that Professor Massonnet has pointed out that providing all other things are equal, a smaller factor of safety with respect to web buckling should be used with high strength aluminium alloy girders than with steel girders, because of the greater reserve of strength in the post-buckled range which is obtained with the former. It was in order to utilise more fully this reserve in the load carrying capacity of the webs of light alloy girders, that the authors recommended that the webplates should be designed to operate in the post-buckled range. When loaded beyond its buckling load, a webplate develops a wavy surface and it is possible that with certain designs, objections, based on aesthetic considerations would be made with respect to the appearance of this wavy surface before the maximum stress in the webplate had reached the maximum permissible stress. In other words, when designing members to operate in the postbuckled range, both aesthetic and strength requirements have to be considered and it is possible that conditions will arise when the former requirement is the controlling one.

The author assures Professor Massonnet that it was not his intention to convey the impression that the effects of web buckling can be disregarded. In fact, the decision to allow webplates to operate in the post-

-buckled range means that it is necessary to understand more fully the effects of web buckling upon the behaviour of the flange members and the stiffeners.

In this connection, one problem which has hitherto not received a great deal of attention is that of the influence of flange rigidity upon the post-buckled behaviour of the webplate. At the present time, many girders are being designed with flanges which have a low flexural rigidity about an axis (xx) perpendicular to the webplate, see Fig. 1. These flange members are not capable of effectively carrying the lateral loads which are imposed upon them by the slightly buckled webplate. The author

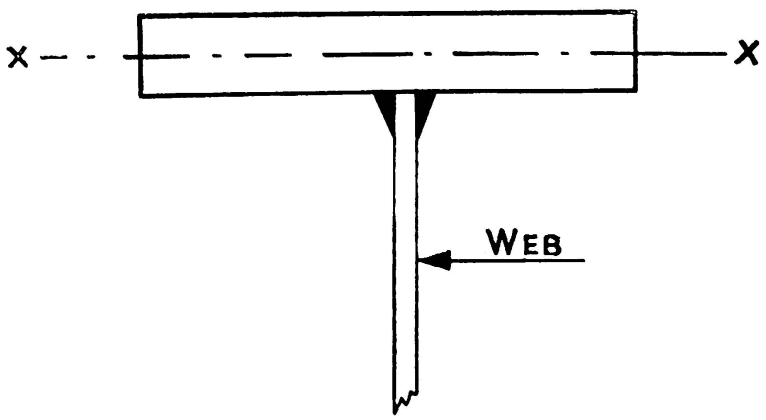

FIG. 1

was therefore very interested to learn that Professor Massonnet has found that by the use of effective horizontal stiffeners he has been able to increase the failing load of such flange members. The author agrees with Professor Massonnet that it is necessary to use flanges which have a greater flexural rigidity about the xx axis. The experimental work which Professor Massonnet is going to conduct on girders of the Doren type, see his figure 2b, will therefore be a most valuable contribution, and the results of this work will be awaited with interest.

The problem of designing the flange-stiffener combination of plate girders so that an efficient structure is obtained has been studied by the author and his research team at Swansea. The author first became aware of the need of such an investigation some years ago while testing welded steel girders [1]. It was noted that if the flanges possessed a low flexural rigidity about their xx axis, see Fig. 1, they deflected considerably once the buckling load of the panel was exceeded. Since then some 30 girders have been tested to determine the effects of flange rigidity upon the post-buckled behaviour of webplates subjected to shear and to a combination of shear and bending. From this work, curves have been obtained which provide values of the lateral deflection of the webplate in terms of the effective flexural rigidity of the flanges and the ratio applied load W/buckling load W_{cr}.

This work [2], as yet unpublished in full, has shown that if the flange flexibility of the flanges as represented by the parameter I/b^3t, where

I = flexural rigidity of the flanges about an axis xx through their centroid, see Fig. 1;
b = Spacing of vertical stiffeners;
t = Thickness of webplate;

is reduced below a given value the webplate will develop excessively large deflections and it is recommended that girders should be designed so that the value of the parameter I/b^3t shall not fall below the values given in equation 1.

$$\frac{I}{b^3t} = 0.00035 \left[\frac{W}{W_{cr}} - 1\right] \qquad (1)$$

(but not less than 0.00035).

With respect to the design of intermediate vertical stiffeners, the empirical relationships between the size and spacing of vertical stiffeners and the buckling stress of the webplate which are given in the author's paper, see equations 1 to 5, were obtained from elastic tests and these relationships can therefore be used for either steel or aluminium construction. The value γ_L will ensure that the stiffeners are straight when the webplate buckles. From the tests on aluminium girders, it has been found that providing flange failure is prevented, little gain in ultimate strength is obtained by employing stiffeners having a flexural rigidity greater than EI_L. However, the author would agree that if the requirement that the stiffener is to remain straight up to failure, as laid down by Professor Massonnet, is to be achieved, then it would be necessary to employ stiffeners having a flexural rigidity greater than EI_L.

Professor Massonnet has referred to the difference in requirements with respect to post-buckled behaviour of stiffener webplates made by various authorities. The requirements he imposes are more severe than those required in the United Kingdom and he will no doubt be interested to learn that in the United Kingdom it is proposed [3] to permit the use of slightly buckled webs in steel plate girders.

Professor Massonnet has referred to the fact that the first series of tests conducted at Swansea have dealt with webplates stiffened only by vertical stiffeners, whereas he has concentrated more on the behaviou of horizontal stiffeners. Since preparing his paper, the author has commenced investigations to examine the behaviour of webplates stiffened by both horizontal and vertical stiffeners. This work is well advanced, and it is hoped that it will enable a design procedure, utilising both horizontal and vertical stiffeners, to be developed for aluminium girders.

REFERENCES

1. K. C. ROCKEY — *Stability problems associated with the design of plate girder webs.* Civ. Eng., London, vol. 47, p. 821 (Oct. 1952); p. 918 (Nov. 1952), vol. 48, p. 66 (Jan. 1953).
2. Discussion of Structural papers Nos. 48 and 49. Proceedings of the Institution of Civil Engineers, part III, vol. 5, August 1956, No. 2, p. 490-493.
3. Draft Copy B. S. 153 — *Girder Bridges.*

SUMMARY

The significance of plate buckling is discussed and the factors affecting the choice of design stresses are examined. Attention is drawn to the influence of flange rigidity upon the post-buckled behaviour of webplates subjected to shear, and an empirical rule is presented which recommends the minimum flexural rigidity which flanges should possess. The influence of the rigidity of vertical stiffeners upon the ultimate strength of webplates is also discussed.

ZUSAMMENFASSUNG

Die Bedeutung des Beulens von Platten wird diskutiert und die Faktoren, welche die Wahl der zulässigen Spannungen bestimmen, werden untersucht. Die Aufmerksamkeit wird auf den Einfluss der Flanschsteifigkeit auf das Verhalten der ausgebeulten, Schubbeanspruchung unterworfenen Stehbleche gelenkt, und es wird eine empirische Regel zur Bestimmung der minimal erforderlichen Biegesteifigkeit der Flanschen angegeben. Der Einfluss der Steifigkeit der vertikalen Aussteifungen auf den Bruchwiderstand der Stehbleche wird ebenfalls diskutiert.

RESUMO

O autor discute o significado da encurvadura de uma placa e examina os factores que influem na escolha das tensões admissíveis. Chama a atenção para a influência da rigidez dos banzos sobre o comportamento das almas submetidas ao corte, depois de encurvadas e indica uma fórmula empirica que permite determinar o valor mínimo da rigidez de flexão dos referidos banzos. O autor também discute a influência da rigidez dos reforços verticais sobre a carga de rotura das almas das vigas.

RÉSUMÉ

L'auteur discute la signification du voilement des plaques et examine les facteurs qui affectent le choix des contraintes admissibles. Il attire l'attention sur l'influence de la rigidité des semelles sur le comportement des âmes soumises à l'effort tranchant après voilement et présente une formule empirique donnant la rigidité à la flexion minimum que doivent avoir ces semelles. Il discute encore de l'influence des raidisseurs verticaux sur la charge de rupture des âmes.