Carrying capacity of plate girders

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Carrying Capacity of Plate Girders *)

Résistance des poutres à âme pleine

Tragfähigkeit von Vollwandträgern

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The purpose of an extensive research project conducted at Lehigh University was to investigate the carrying capacity of plate girders with slender webs. In the paper "Web Buckling Tests on Plate Girders" in the Preliminary Publication of the 6th Congress parts of the experimental findings were presented. A complete report on the experiments is given in Ref. [1]. The publication of the theoretical studies is in preparation. The following is a summary of the basic concepts on which these strength predictions are based.

a) *Bending strength.* Experiments as well as the large deflection theory show that web buckling produces essentially a rearrangement of the internal stresses. Due to unavoidable initial plate deflections in webs of girders, this rearrangement is not a sudden phenomenon. There are two kinds of post-buckling strength; one is offered by the plate, the other is contributed by the boundary elements. Assuming the web area of a plate girder equals that of each flange plate, at least 85 per cent of the bending moment is carried by the flanges alone. Therefore, the rest assigned to the web is of minor importance for the carrying capacity. A simple estimate of an effective width of the web adjacent to the compression flange is sufficient for the computation of the resulting bending moment. The ultimate moment, however, is reached at the instant of a flange failure.

If the compression flange fails, three different failure modes are possible: vertical buckling of the flange plate into the web, torsional buckling of the

*) Supplement to "Preliminary Publication" VI, page 907.

flange plate, and lateral buckling of the compression flange. The first type is controlled by specifying an upper limit for the web slenderness ratio. The second mode is dependant on the ratio of flange width to flange thickness. The treatment of the third case, lateral buckling, reduces to an analysis of a column whose effective cross section is composed of the compression flange and one-sixth of the web.

b) *Shear strength.* The prediction of the shear strength is based on the following three essential assumptions: First, shear can be carried in strict beam action only up to the critical load. Second, a rearrangement of stresses must then take place which amounts to a tension field action and, third, the ultimate shear force is reached when the superposition of these two states of stresses causes unrestricted yielding.

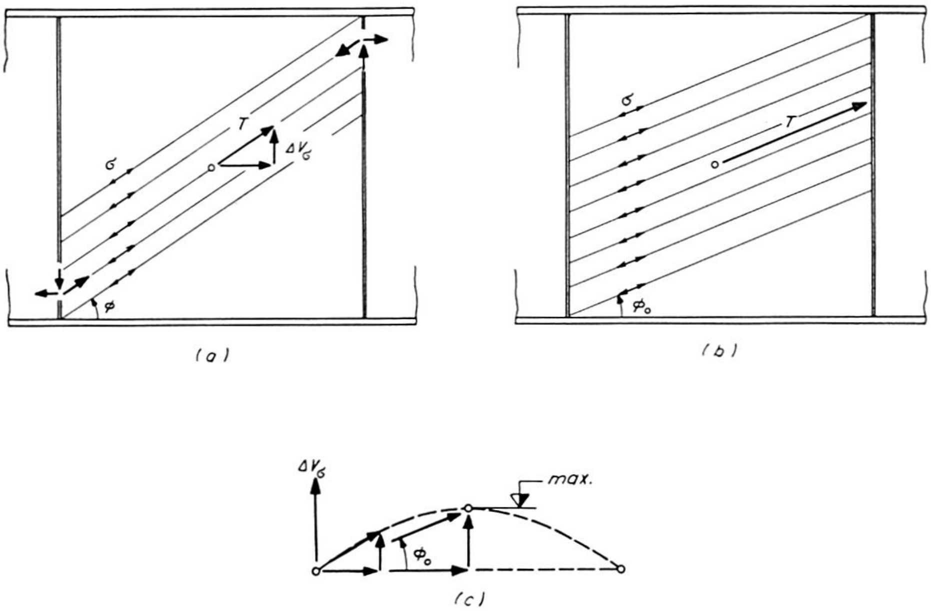

Fig. 1. Tension Field Action.

Whether a tension field, which is a membrane stress field, can develop or not depends on the boundaries of the plate. The flanges of a conventionally built, welded plate girder have little bending rigidity in the direction of the web. Hence, they cannot effectively exert any normal stress at the junction with the web. The flanges, therefore, do not serve as anchors for a tension field. The situation is however different at the panel borders along the transverse stiffeners. As shown in the left hand sketch of Fig. 1, such a field strip gives rise to a tension force T whose vertical component, ΔV_σ, represents the shear force carried in this manner. It is obvious that, upon increasing the applied shear force, the tension field widens as shown on the right of Fig. 1. However, because the increase in width is gained on account of the field inclination, an optimum value of the tension field contribution will soon be reached, Fig. 1c. Based on these considerations the following formula for the ultimate force V_u results [2]:

$$\frac{V_u}{V_p} = \frac{\tau_{cr}}{\tau_y} + \frac{\sqrt{3}}{2} \frac{1 - \frac{\tau_{cr}}{\tau_y}}{\sqrt{1+\alpha^2}}.$$

V_p is the plastic shear force, defined as the shear yield stress times the web area. The symbols τ_{cr} and τ_y are the critical shear stress and the yield stress in shear, respectively, while α is the ratio of stiffener distance to web depth.

c) *Interaction between bending and shear.* The shear strength, as outlined above, makes no use of the flange as anchor for the tension field. Therefore, the ultimate shear strength should not be reduced by the presence of a bending moment as long as the flanges alone are able to carry this moment. Hence, it is only the small part of the bending moment which is assigned to the web that leads to an interaction. While equilibrium is always possible, compatibility conditions are disregarded with such a separation of functions assigned to different components of the girder. This is tolerable to a large degree because a girder with a stocky web can rearrange its forces through yielding, whereas a slender web makes it possible by deflecting laterally.

The investigation, of which the contributions in the Preliminary and Final Report are excerpts, was conducted at Fritz Engineering Laboratory, Lehigh University, Bethlehem, Pennsylvania. It was sponsored jointly by the American Institute of Steel Construction, the U.S. Bureau of Public Roads, the Welding Research Council, and the Pennsylvania Department of Highways.

References

1. Basler, K., Yen, B. T., Mueller, J. A., and Thürlimann, B. "Web Buckling Tests on Welded Plate Girders". Welding Research Council, Bulletin No. 64, New York, 1960.
2. Basler, K. "Strength of Plate Girders". Ph. D. Dissertation, Mic. 59–6958, University Microfilms Inc. Ann Arbor, Michigan.

Summary

In the report "Buckling Tests on Plate Girders" (Preliminary Publications, 6th Congress, Thema VI) a selection of experimental results obtained on girders in pure bending and high shear was presented. In this paper theoretical considerations concerning the static strength of girders in bending, shear or combined bending and shear are presented without going into details at all. A more detailed study on the carrying capacity of plate girders along these lines is presently in progress.

Résumé

La contribution intitulée «Essais de voilement sur poutres à âme pleine» («Publication Préliminaire», 6e Congrès, Thème VI) présentait un choix de résultats d'essais effectués sur des poutres soumises à une flexion pure ou à un cisaillement élevé. Le présent article contient quelques réflexions théoriques sur la résistance des poutres à âme pleine soumises à la flexion, au cisaillement ou à une sollicitation combinée, sans toutefois entrer dans les détails. Des études plus poussées, partant des résultats obtenus jusqu'ici, sont actuellement en cours.

Zusammenfassung

Im Beitrag «Beulversuche an Vollwandträgern» (Vorbericht 6. Kongreß, Thema VI) wurde eine Auswahl von Versuchsresultaten gezeigt, welche an Vollwandträgern unter reiner Biegung oder hohem Schub beobachtet wurden. Hier wurden nun einige theoretische Überlegungen über die statische Tragfähigkeit von Vollwandträgern unter Biegung, Schub und kombinierter Beanspruchung kurz dargelegt, ohne auf Einzelheiten einzugehen. Detaillierte Studien, die auf diesen Überlegungen fundieren, sind gegenwärtig im Gange.