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### III

#### **Prepared Discussion in regard to the Post-Buckled Behaviour and Incremental Collapse of Webs Subjected to Concentrated Loads**

Discussion préparée du thème:

"The Post-Buckled Behaviour and Incremental Collapse of Webs Subjected to Concentrated Loads"

Vorbereitete Diskussion zum Thema:

"The Post-Buckled Behaviour and Incremental Collapse of Webs Subjected to Concentrated Loads"

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#### **Introductory Remarks**

The investigation /1/, /2/ into the post-buckled behaviour of webs in shear having been completed, a new research project regarding the ultimate load behaviour of plate girders was started in Prague. This deals with the effect of flange stiffness upon the ultimate load performance of thin webs subjected to a) static and b) variable repeated concentrated loads, which are applied to the flange of the girder at the mid-distance of the vertical stiffeners of the web. This problem is frequently encountered in the design of crane girders, certain types of bridge girders and similar structures, and also in the case of girders without vertical stiffeners (see the very interesting contribution by Bergfelt /3/). The objective of our new research is to study not only the static failure mechanism of such girders, but also the deflection stability of the web under variable repeated, cyclic loading, and the incremental collapse of the web and the whole girder.

#### **Test Girders and Apparatus**

The aforesaid research project consists, in the first stage, of testing 8 steel panels shown in Fig. 1 and 7 large-scale steel test girders. Further test series will follow. Some of the panels and girders are subjected to static loads, the others to cyclic pattern loading.

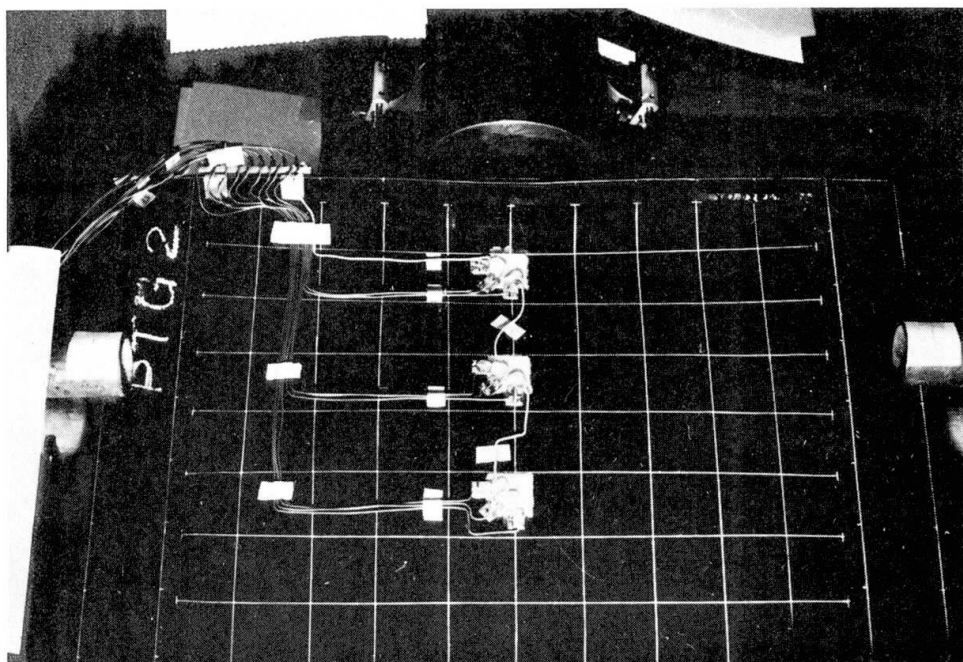


Fig. 1.

The research on steel girders is accompanied by a photoelasticity investigation conducted by the first of the authors and J. Kratěna on reduced-scale epoxy-resin models.

The buckled pattern of the web is measured by means of a stereophotogrammetric method which has been established by one of the authors /4/. One of the advantages of this method consists in making it possible to measure not only the web deflection perpendicular to the web, but also the other two components of the spatial displacement vector of any point of the web and flanges. Thus it is possible, for instance, to evaluate the distortion, in terms of load, of the projection of the mesh that was marked on the web, and which serves as a basis for the determination of the contour maps of the buckled surfaces of the web. The distortion of the projected mesh is not negligible, as can be seen in an enlarged scale in Fig. 2, this being particularly the case in the vicinity of the applied load. The contour plots of the buckled surface of the

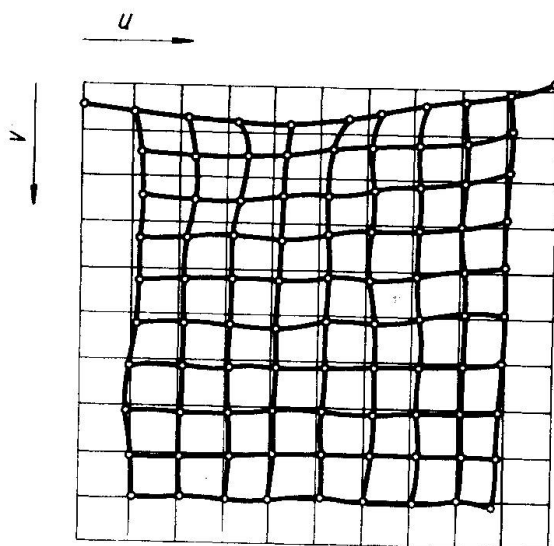


Fig. 2.

web are then related to the distorted mesh and to the deformed boundary framework of the web panel.

The contour map of the post-failure plastic residue in a web panel, subjected to a concentrated load at the mid-distance of the vertical stiffeners, and in the deflected flange are shown in Fig. 3.

The stereophotogrammetric method is also successfully used to measure the web buckled pattern and the flange deflection in the cyclic loading tests. An oscilloscope "Disa" and additional apparatus (Fig. 4) enable the writers to measure the deformation at any time moment of a loading cycle - for instance, at the moment when the deflection amplitude is reached.

The stress state in the web and flanges is measured by numerous electric resistance strain gauges. In the case of cyclic loading, some of the strain gauges and dynamic deflection pick-ups are linked to an automatic recorder "Ultralette", which records

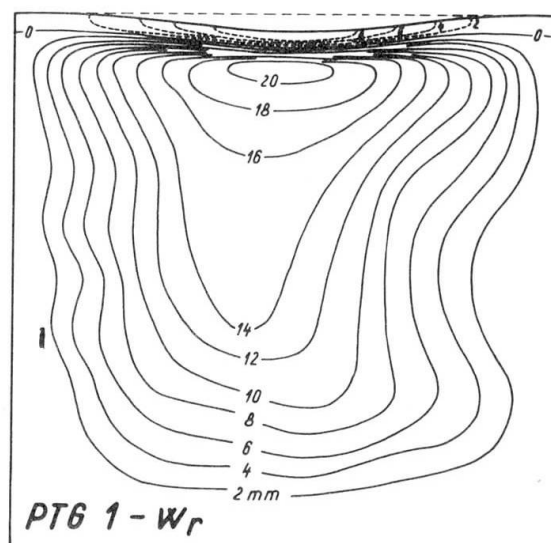


Fig. 3.

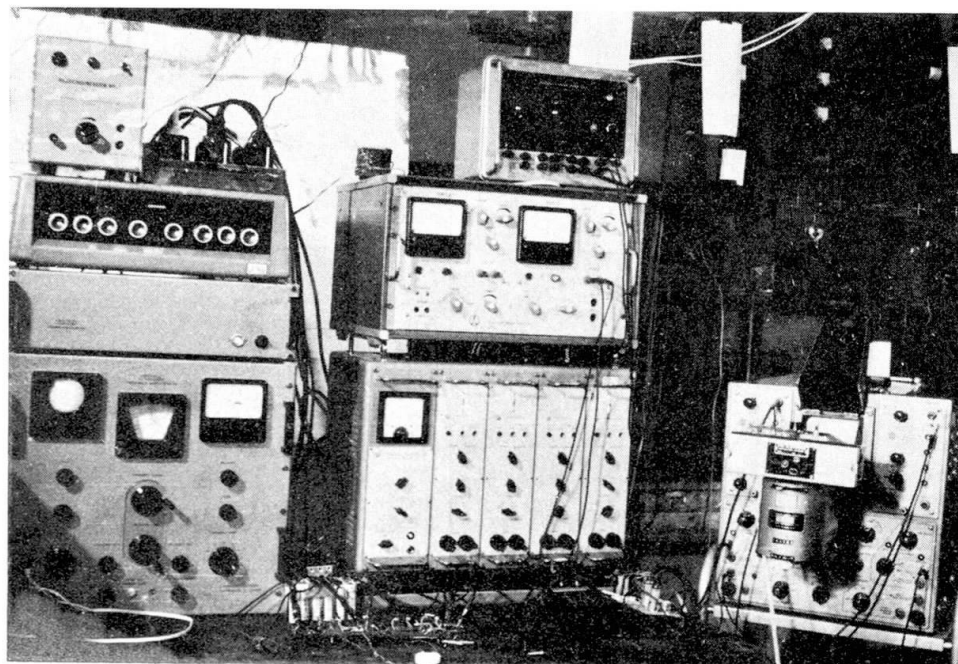


Fig. 4.

the corresponding signals on recording paper (see Fig. 5, showing an increase in web deflection during cyclic loading).

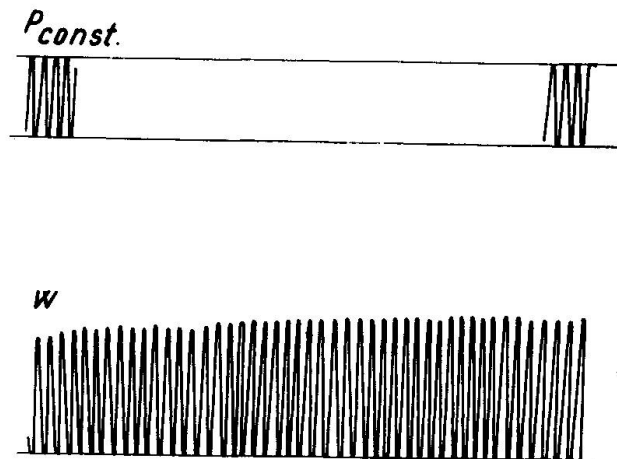


Fig. 5.

### Test Results

An analysis of the static test results indicates that thin webs subjected to concentrated loads manifest a considerable post-critical reserve of strength, which ought to be taken into account in the design of steel plate girders.

The load-carrying capacity of such webs is significantly affected by the flexural rigidity of flanges. While for web panels attached to flexible flanges, whose  $I_f/a^3t = 3.49$  ( $I_f/a^3t$  denoting the same flange stiffness parameter as was used in /1/, /2/), the ratio ultimate load  $P_{ult}$ /critical load  $P_{cr} = 1.73$ : in the case of webs attached to heavier flanges,  $I_f/a^3t = 63.5$ , the same ratio amounted, on an average, to 2.445.

In the tests on plate girders subjected to variable repeated loading, the question of stability of post-critical web deflection is of importance.

When the girder operates in the plastic range, an increase in web deflection during a certain number of loading cycles is noted (Fig. 5). The problem is then to determine the maximum load for which these deflection increments cease after a limited number of cycles of load application, and the structure then responds to the load in a purely elastic manner. The corresponding load, which is referred to as the "stabilizing load", is the highest force the girder can sustain. Any further increment in load brings about a breakdown of the girder through incremental collapse.

Fig. 5 relates to a load which was practically equal to the "shake-down load" of the test girder. A slight further increment in load caused instability of web deflection and, shortly afterwards, a collapse of the girder.

A complete report on the above mentioned research project will appear shortly after the completion of the tests.

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