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# Prepared Discussion in Regard to the Ultimate Load Behaviour of Webs in Shear

Discussion préparée concernant le comportement à la ruine des âmes soumises au cisaillement

Vorbereitete Diskussion zum Traglastverhalten schubbeanspruchter Stehbleche

M. ŠKALOUD
Doc., C.Sc., Ing.
Senior Research Fellow
Czechoslovak Academy of Sciences
Institute of Theoretical and Applied Mechanics
Prague, Czechoslovakia

## Introductory Remarks

Some of the 'failed' test girders of the research project described in /1/ were tested once more in the upside-down position. This was decided in the hope that the diagonal plastic buckled pattern which formed in the first test would beneficially affect the wave pattern developing during the second test and perpendicular to the first one.

The test results are included in the final report /2/, which will appear shortly.

The main observations can be summarized as follows:

## Buckled Pattern of the Web

The buckled pattern of a web panel of 'failed' girder TG 5' tested once more in the upside-down position is shown in Fig. 1. Fig. 1a shows the girder before the test, and Fig. 1b relates to the final stage of the test in the upside-down position, showing the buckled surface of the web shortly before the failure of the girder.

The process of web buckling is as follows:

In the first stage the new buckled pattern is governed by the wave pattern resulting from the first test and being perpendicular to the new one; therefore, the newly developing diagonal half-waves have to overcome the effect of the

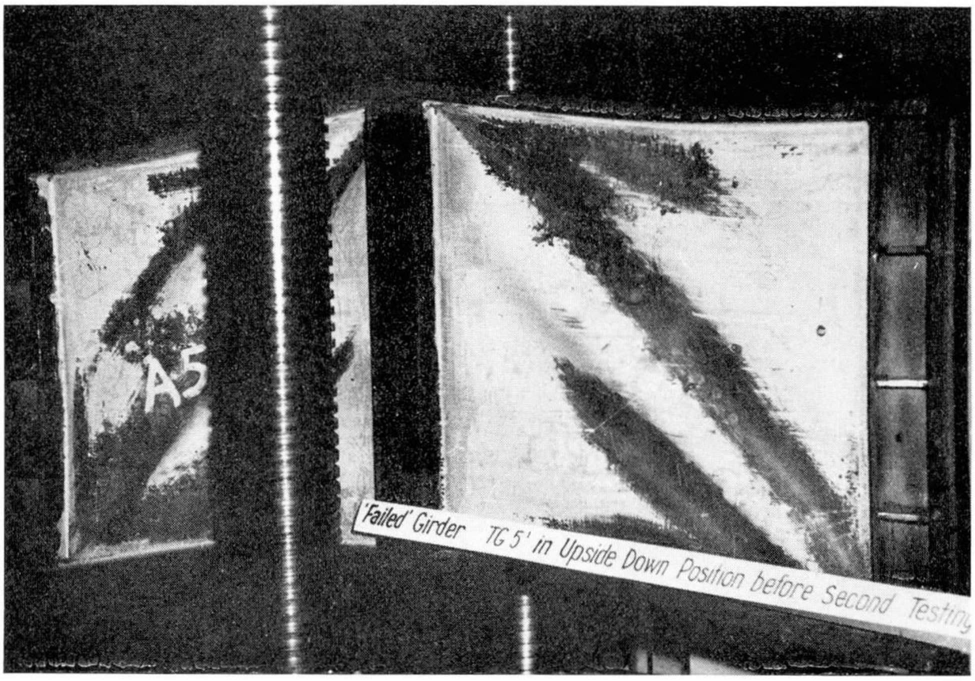
A5
'Failed' Girder TG 5' in Upside Down Position before Second Testing

Fig. 1a

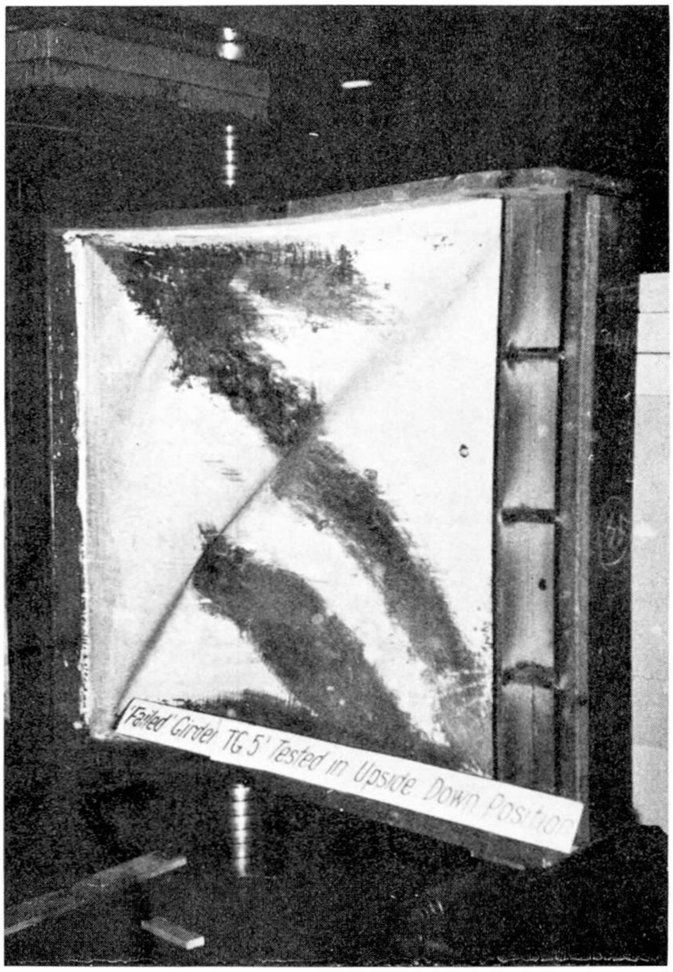
'Failed' Girder TG 5' Tested in Upside Down Position

Fig. 1b

perpendicular waving, which, in a sense, stiffens the web. In other words, the diagonal middle plane stresses forming during the upside-down test have to make the web again more or less plane; and only then can the new diagonal buckled pattern form and grow monotonously up to the collapse of the girder.

Deflection of the Girder

The deflection of a girder tested in the upside-down position is shown in Fig. 2, in comparison with the deflection of the same girder tested earlier in the normal position.

It can be seen there that the process of deformation can be divided into three stages.

In the first one, the web is stiffened by the waving which formed in the first test; therefore, the deflection $y_{II}$ of the girder grows fairly slowly, and is less than that which developed in the first test ($y_I$).

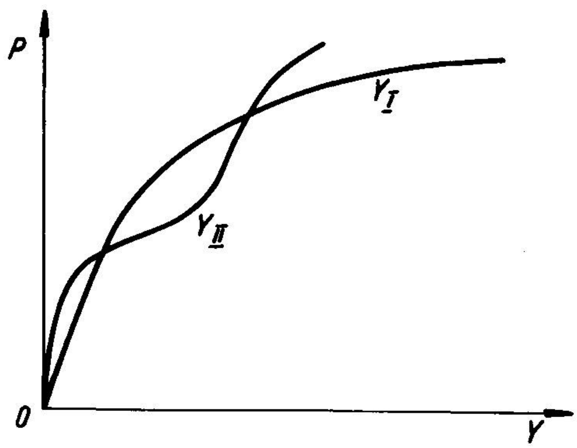


Fig. 2.

In the second stage, during which the buckled pattern of the web changes rapidly from the original deformation to the new diagonal wave pattern, the rigidity of the web (and, accordingly, also that of the whole girder) is substantially lessened. Therefore, the rate of deflection considerably enlarges.

In the third stage, the new buckled pattern (and the corresponding stabilizing effect of membrane stresses) predominates, the behaviour of the girder again stabilizes, and the growth of the girder deflection slows down. The deflection then increases monotonously up to the failure of the girder. This final stage is similar to the performance of the original girder tested in the normal position.

Ultimate Load

The ultimate loads $P^{II}_{ult}$ of failed girders TG 1′, TG 3′ and TG 5′, tested once more in the upside-down position, are listed in Table 1, and compared to the load-carrying capacities $P^{I}_{ult}$ of the same girders obtained in the first test.

An analysis of the table shows that the ratio $P^{II}_{ult}/P^{I}_{ult}$ depends on the flexural rigidity of flanges. The ultimate strength $P^{II}_{ult}$ of girder TG 1′, the flanges of which were very flexible, was lower than the load-carrying capacity $P^{I}_{ult}$. On the other hand, the ultimate loads $P^{II}_{ult}$ of girders TG 3′ and TG 5′ having rigid flanges, were as high as those in the first test. More accurately, the ′failed girder TG 3′ was able to sustain in the second test practically the same load as it did in the first test, it which it still operated as a new girder, delivered from a steel structure plant. ′Failed′ girder TG 5′, which had very heavy flanges, sustained, when tested once more in the upside-down position, a load that was higher than the load-carrying capacity $P^{I}_{ult}$ of the same girder in the ′virgin′ state. Consequently, the ′failed′ girder tested in the upside-down position behaved better than the original one.

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Conclusion

The aforementioned information can be regarded only as preliminary. Further evidence in this line is necessary. None the less, having analysed the afore said results, Professor Faltus and the author are inclined to believe that a procedure

Table 1

| Girder | $I_f/a^3t$ Units of $10^{-6}$ | $P_{ult}^{I}$ tons | $P_{ult}^{II}$ tons |
|---|---|---|---|
| TG 1' | 0.762 | 23.7 | 11.8 |
| TG 3' | 29.55 | 38.7 | 38.3 |
| TG 5' | 218.5 | 61.18 | 63.5 |

similar to that which is mentioned above could be used to 'prestress' web panels in shear, and thereby improve the behaviour of the whole girder. The procedure would consist in subjecting the girder to a load which would induce in the web a slight plastic buckled pattern perpendicular to that which is anticipated to occur under service load.

Of course, the plastic residues in the webs of girders TG 1', TG 3' and TG 5', which developed in an up-to-failure test, were too large. The prestressing buckled pattern would have to be limited to an extent of being just able to create the beneficial diagonal waving, its ordinates being, however, small enough to have no disturbing aesthetical (and psychological) effect.

References:

/1/ Škaloud, M.: Ultimate load and failure mechanism of thin webs in shear. Paper presented at the IABSE Symposium "Design of Plate and Box Girders for Ultimate Strength". London, March, 1971.

/2/ Škaloud, M. and Zörnerová, M.: Post-buckled behaviour of webs in shear, attached to flanges of various flexural rigidities. Czechoslovak Academy of Sciences - Institute of Theoretical and Applied Mechanics 1971.