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LINDNER, Joachim (1), HUANG, Bin (2)

PROGRESS IN THE ANALYSIS OF BEAMS WITH TRAPEZOIDALLY CORRUGATED WEBS

ABSTRACT

Beams with trapezoidally corrugated webs show a great shear capacity although the web is very thin. It can be shown by tests and theoretical investigations that a kind of tension field occurs at the ultimate limit stage. But the type of vertical corrugation leads to additional warping stresses in the flanges. This influences the buckling behaviour of the compression flange, which may be taken into account by different buckling coefficients k_σ.

1. INTRODUCTION

I-beams subjected to bending are designed with regard to bending moments and shear forces mainly. Economical design of beams normally requires thin webs. But if the web is extremely thin the problem of plate buckling may arise. Possible ways to reduce this risk consist in using thicker plates, web stiffeners or strengthen the web by corrugated plates, see Fig. 1.

Beams and girders with corrugated webs have been manufactured in several countries for more than 20 years. They were mostly used for building structures. Especially in Sweden large numbers of industrial buildings were erected with this type of beams. The use

(1) Univ.-Prof. Dr.-Ing., Technische Universität Berlin, Germany
(2) Dr.-Ing., PR China, working: Techn. Univers. Berlin, Germany

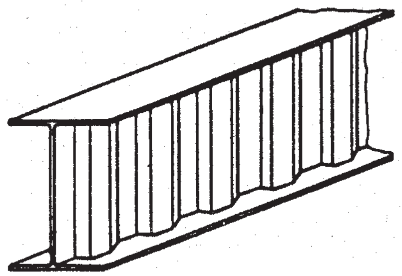

Figure 1
Beam with trapezoidally corrugated web in vertical position

of corrugated webs was the result of the research work conducted at Chalmers University of Technology in Göteborg, (ref.1). But recently also bridge structures were built with this type of web in France. Beams with trapezoidally corrugated webs were used in a small number of industrial buildings in Germany too. They were erected by granting of a special licence, because no general rules or specifications in codes were available. Just recently a new recommendation (ref.2) containing general rules was published. Those rules are based on the data which were achieved from the Swedish investigations (ref.3).

Slender beams may also fail by lateral-torsional buckling, which is a combination of lateral bending and twisting. The achieved out-of-plane stiffness and torsional rigidity of trapezoidally corrugated webs were investigated by Lindner (ref.4). An overall view on the problems concerning beams with corrogated webs are given in (ref. 8).

2. SHEAR CAPACITY OF WEBS WITHOUT OPENINGS

The only code which deals with beams with corrugated webs is given by (ref. 2). Local buckling and global buckling must be taken into account in order to obtain the shear capacity. The formulae given are based on the Swedish investigations, especially the test results.

Some tests show that at the ultimate limit stage a tension field too occured. This effect is well known from flat webs. In the analysis due to (ref. 2) or (ref. 7) this is taken into consideration for flat webs by using a modified tension field model. Following (ref. 2) the ultimate shear force V_{Rd} consists of V_{pd} and V_{Zd} :

$$V_{Rd} = V_{Pd} + 0.85\ V_{Zd} \qquad (1)$$

where

V_{Pd} = shear force due to local buckling
V_{Zd} = shear force due to tension field action

The factor 0.85 in eq. (1) was introduced in order to adjust theoretical results to test results.

One may expect that a similiar modified tension field model will give satisfying results for corrugated webs too. Therefore investigations were carried out to determine buckling coefficients k_τ for corrugated panels. The calculations were done by the Finite Element Method using the computer Program ADINA, which is available at the computer centre of Technical University Berlin. Most calculations were done using a representative part of the whole web only, see Fig.2.

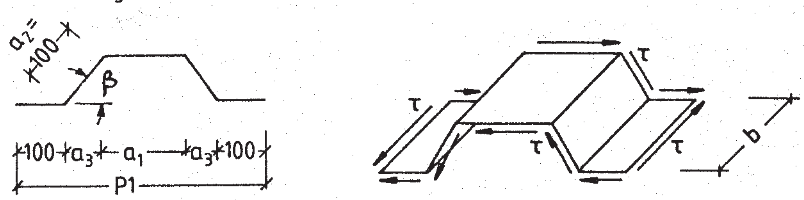

Fig. 2. Part of the web investigated

Several parameters are investigated. Results for different angles β (see Fig. 2) show that the buckling coefficients k_τ remain constant if the value of β exceeds 30^o. The corresponding values for a variety of values of $\alpha = b/a_1$ are given in Fig. 3. The general behaviour is similiar as for flat plates with simple support or fixed support at the edges. Comparing the values of Fig. 3 with the results of flat plates with free and fixed edges show that an elastic restraint of the plate a_1 in the sloping parts a_2 is present.

Of great interest for the practical design is the question what depth b_t of the corrugation should be used. Results for k_τ for different values of b_t can be seen from Fig. 4.

3. SHEAR CAPACITY OF WEBS WITH OPENINGS

If corrugated webs are used for industrial buildings installation for heating and fresh air may require openings. The load carrying capacity of beams and girders with slender flat webs and openings was studied widely at the University of Cardiff in

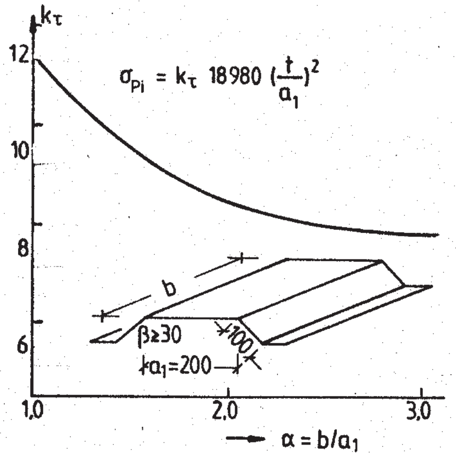

Fig. 3. Buckling coefficients k_τ for different values α

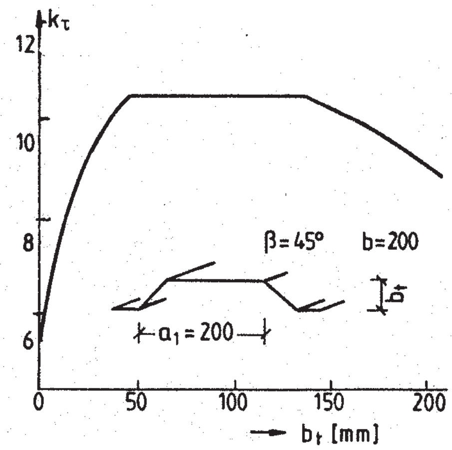

Fig.4.Buckling coefficients k_τ for different values b_t

Great Britain (ref.6). The proposed design procedures are based on the tension field method for slender webs without openings and used in DASt-Richtlinie 015 (ref.2) and Eurocode 3 (ref.7). But there are no information or records on the effect of openings in corrugated webs. Therefore a research program is underway at he Technical University of Berlin dealing with this problem.
First test results were given in ref. 9. These tests were completed in the meantime. In order to make comparisons between test results and an theoretical approach again calculations using the Finite Element Method were carried out. A part of the structure which is shown in Fig. 5 was investigated. Both simple supports and fixed supports at all edges were taken into account but it could be seen that this influences the results of the buckling coefficients k_τ insignificantly only. For a special geometrical configuration coefficients k_τ are given in Fig. 6 depending on the size of the opening.

Looking to typical buckling modes it can be seen that they are similiar for one opening in the middle of the investigated panel and for three openings in following parts.

4. CAPACITY OF THE FLANGES

The compression flange may buckle as a whole which leads to lateral torsional buckling of the entire beam, (ref.4, ref. 8)

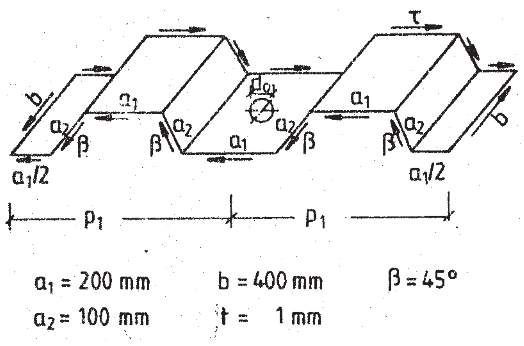

Fig. 5. Corrugated panel with round opening

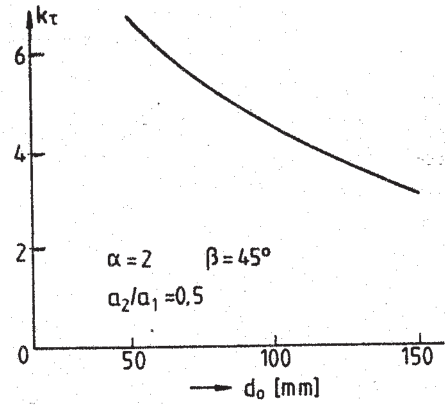

Fig.6.Buckling coefficients k_τ depending on d_o

Furthermore the compression flange may also buckle locally. To deal with this problem several peculiarities must be taken into consideration :

- the buckling panel is not rectangular
- the buckling panel is not supported regularly but at some edges only
- the two part of the flange do interact with eachother
- the normal forces have not a constant distribution due to additional warping stresses forced by the web

Again theoretical investigations using FEM were carried out. Evaluations were made varying the geometrical properties. Some results for the buckling coefficient k_σ are given in Fig. 7

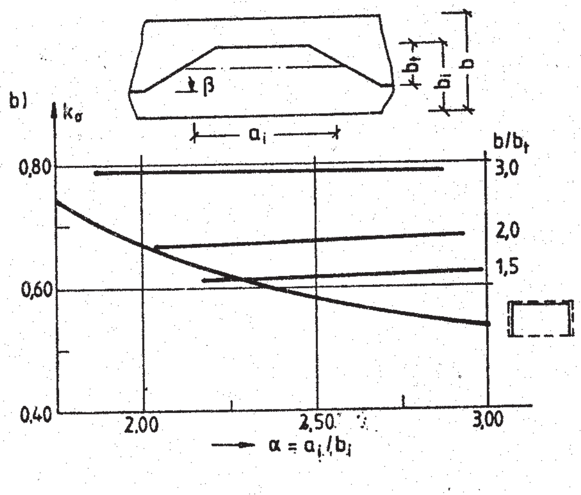

Fig. 7. Buckling coefficients k_σ for flanges of beams with trapezoidally corrugated webs - $b/t = 25$, $\beta = 30^o$

6. ACKNOWLEDGEMENTS

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