

Stress distribution in the flanges of corrugated web girders

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1. Intruduction

The stress distribution in the flanges of the corrugated web girders is analyzed in the recent report. This topic is raised after the proposal of Prof. Ivan Balaž based on the realization that the EN1993-1-5 consist the determination method of the bending moment resistance of the corrugated web girders and this method considers the effect of the additional normal stresses coming from the shear in the corrugated web. But the EN1993-1-5 does not give the determination method of this additional normal stress, what should be taken into account in the bending resistance calculation. Prof. Balaž proposed a formula for the determination of the transverse bending moment which results in the above mentioned additional normal stress in the flanges. Laboratory tests were executed at the Budapest University of Technology and Economics 3 years ago on large scale test specimens with corrugated webs and numerical models are also developed to analyze the different structural behavior of the corrugated web girders (fatigue, patch loading, F+M and F+V interaction behaviour). These investigations are extended now by the analysis of the normal stress distribution in the flanges to make possible to extend the EN1993-1-5 with a new formula to determine the additional normal stresses coming from the shear in the corrugated web.

2. Literature overview

Five previous investigations are found in the literature, which are dealing with the normal stress distribution in the flange of the corrugated web girders.

- [1] B. Johansson, R. Maquoi, G. Sedlacek, C. Müller, D. Beg: „Commentary and worked examples to DIN-EN-1993-1-5 Plated Structural Elements”, 2007.
- [2] R. Aschinger, J. Lindner: „Zu besonderheiten bei Trapezstegträgern”, *Stahlbau*, Vol. 66, No. 3, pp.136–142, Germany, 1997.
- [3] H.H. Abbas, R. Sauce, R.G. Driver: „Behaviour of corrugated web I-girders under in-plane loads”, *Journal of Engineering Mechanics* © ASCE, Vol. 132, No. 8, pp.806-814, August 1, 2006
- [4] H.H. Abbas, R. Sauce, R.G. Driver: „Analysis of flange transverse bending of corrugated web I-girders under in-plane loads”, *Journal of Structural Engineering* © ASCE, Vol. 133, No. 3, pp.347-355, March 1, 2007.
- [5] Proposal of Ivan Balaž, 2011.

All documents give different proposals to determine the additional normal stresses in the flange coming from shear in the corrugated web. All the proposals are using the same theoretical background developed by Aschinger and Lindner [2] in 1997, but the

formulation of equations to determine the maximum transverse bending moment are different.

Proposal of the “Commentary and worked examples to DIN-EN-1993-1-5 Plated Structural Elements”

In [1] there is a possible determination method of the maximal transverse bending moment, what results in the additional normal stresses in the flanges. The proposed equation is shown in Fig. 1. But there are no background of the proposed formula, only the final equation is given. The below mentioned equation is still not in the Eurocode, only in the “Commentary” document.

If there is a substantial shear force in the cross section of maximum bending moment there may be an influence of the flange axial resistance from lateral bending. Rules for this have been included in the German design rules [2]. A model for calculating these secondary bending moments is shown in Figure 13.3. The shear flow in the web will be constant V/h_w and its effect can be modelled as shown in the lower part of Figure 13.3. The maximum transverse bending moment $M_{z,max}$ occurs where the inclined part of the web intersects the centreline of the flange. It becomes:

$$M_{z,max} = \frac{Va_3}{4h_w}(2a_1 + a_4) \quad (13.1)$$

where V is the coexisting shear force and other notations are according to Figure 13.2.

Fig. 1: Proposal of the „Commentary and worked examples to DIN-EN-1993-1-5 Plated Structural Elements”.

Proposal of Aschinger and Lindner

In [2] there is an another equation given to determine the additional normal stresses in the flange. The theoretical background of this equation is that the additional bending moment comes from the shear flow in the corrugated web. This shear flow has different directions along the girder length in the parallel and in the inclined folds which results in an additional transverse bending moment in the flanges. The shear flow has an alternating tendency therefore the additional stress distribution has also an alternating tendency. The aims of the proposals are to determine the maximum additional bending moment.

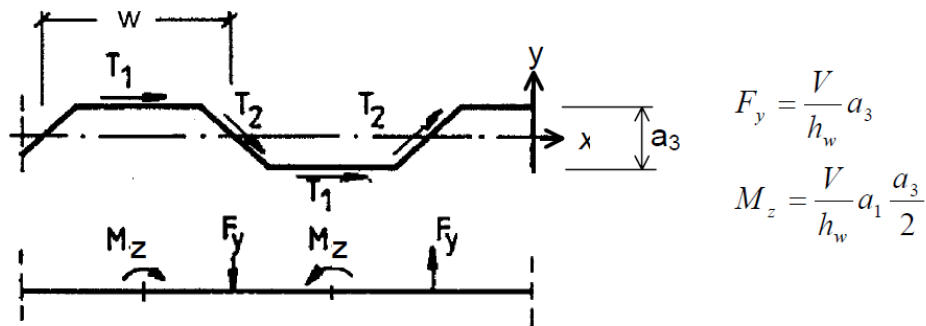


Fig. 2: Theoretical background of the transverse bending moment [2].

The proposed maximum additional bending moment in [2] can be expressed in form of Eq. (1).

$$M_{z,\max} = C_1 \cdot F_y + C_2 \cdot M_z \quad (1)$$

where: C_1 and C_2 are constants which are depending on the loading conditions of the analyzed girder. The relevant values of C_1 and C_2 are given in Table 1.

Table 1: Values of C_1 and C_2 constants.

	C_1 [1/cm]	C_2 [...]
uniformly distributed load	6,5	0,6
concentrated force	13,0	1,5
concentrated moment	13,0	2,0
triangle distributed load	6,5	0,5

The proposed equation of [2] is proved by laboratory test results. The stress distribution in the corrugated web girder was measured and compared to the given proposal, and the comparison showed a good agreement. Therefore the above mentioned equation was implemented in the DAST-Richlinie 015 "Träger mit schlanken Stegen".

Proposal of Abbas et al.

Research of Abbas et al [3], [4] deal with the same problem as [1] and [2] but it has a different theoretical background. They realized that the shear stresses in the flanges are different on the two sides of the web in a cross section with a parallel fold, that results in out-of-plane torsion of the corrugated web girders under in-plane loads as well, and it results in an additional normal stress in the flanges.

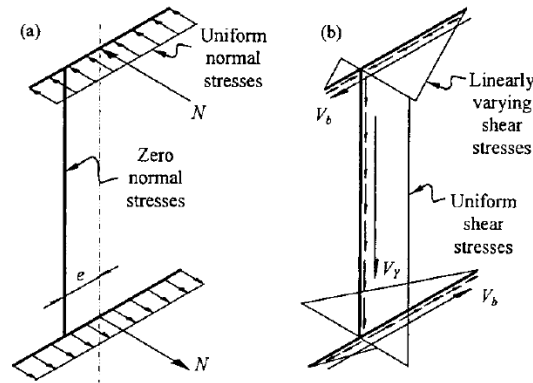


Fig. 3: Stress distributions due to in plane bending and stress resultants.

A closed form equation is developed to determine the transverse bending moment what takes this torsion effect into account. To derive a closed form equation the trapezoidally corrugated web is replaced by a sinusoidally corrugated web, to make the analytical solution easier. The proposed equation is given in form of Eq. (2). All the details of the analytical solution and the relevant notations are given in [3].

$$M_t = \frac{p_y \cdot L^2 \cdot a_3}{2 \cdot h_w} \cdot \left\{ \frac{1}{\Pi^2} \cdot [(1-2\zeta) \cdot \Pi \cdot c_\zeta + 2 \cdot s_\zeta + (\Pi \cdot c_\Pi - 2 \cdot s_\Pi + \Pi) \cdot \zeta - \Pi] \right\} \quad (2)$$

where: p_y is the distributed in-plane load,
 L is the span of the analyzed girder,
 a_3 is the corrugation depth,
 h_w is the web depth,

$$\text{and } \zeta = z/L; \quad \Pi = 2 \cdot \pi \cdot n; \quad c_\zeta = \cos(2 \cdot \pi \cdot n \cdot \zeta); \quad c_\Pi = \cos(2 \cdot \pi \cdot n);$$

$$s_\zeta = \sin(2 \cdot \pi \cdot n \cdot \zeta) \quad \text{and} \quad s_\Pi = \sin(2 \cdot \pi \cdot n)$$

To determine the transverse bending moment of the trapezoidally corrugated web girders a so called “fictitious load method” is developed. A fictitious load p_t is introduced as a tool for analyzing flange transverse bending of corrugated web I-girders. This load is defined as the transverse load per unit length of flange that produces the internal flange forces V_t and M_t . As the transverse load p_t is not actually present in the real problem, it is referred to as a “fictitious” load and it is determined from equilibrium of an element of infinitesimal length cut from the flange, as shown in Fig. 4.

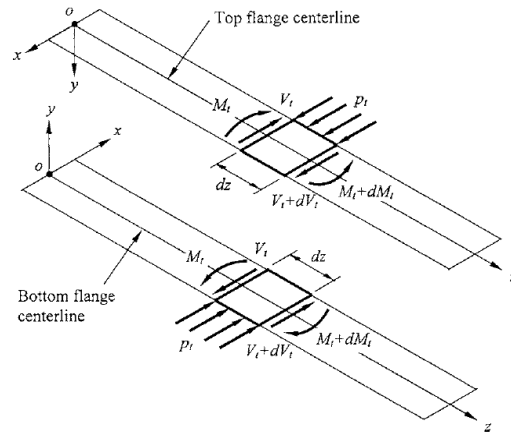


Fig. 4: Transverse fictitious loads.

The given analytical solution is compared to strain measurements in laboratory tests made on large scale test specimens with trapezoidally corrugated web and to numerical calculations. The details of the tests are given in [4].

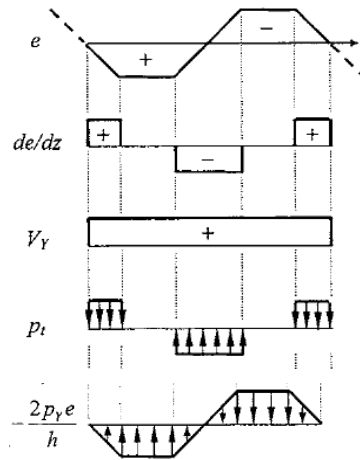


Fig. 5: Fictitious loads in the flange of the corrugated web girders.

Conclusion after the comparison of the test results and analytical and numerical solution was if once the fictitious loads are determined (Fig. 5), the flange transverse bending problem can be solved using conventional structural analysis (Fig. 6).

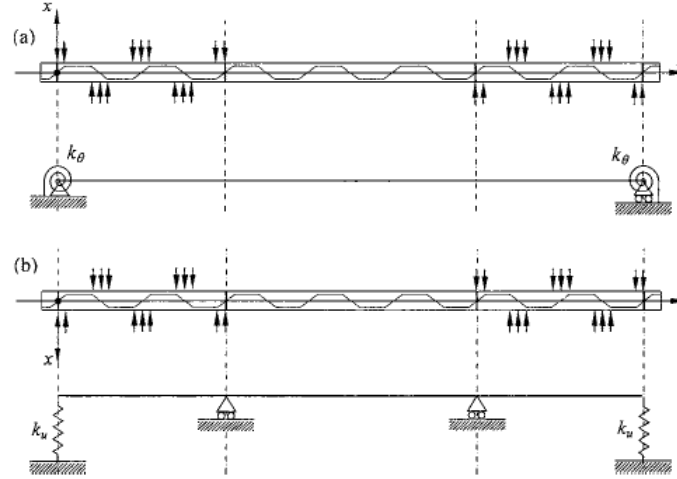


Fig. 6: Mechanical model to determine the transverse bending moment in the lower (a) and upper (b) flanges.

Due to the complexity of the given proposal for the determination of the transverse bending moment, its usage in the praxis is quite difficult. Although manual calculation is also possible, the authors propose that it is often more convenient to use commercial structural analysis software, especially as the number of corrugations increases.

Proposal of Ivan Balaz

The formulation of the proposal in [5] is the same as in [1]. But more theoretical background and derivation of the given equation is also attached. Furthermore a very expressive figure (Fig. 7) about the reason of the additional bending moment is also given. The implementation of a drawing like Fig. 7 into the current version of the EN1993-1-5 could be useful to the designers.

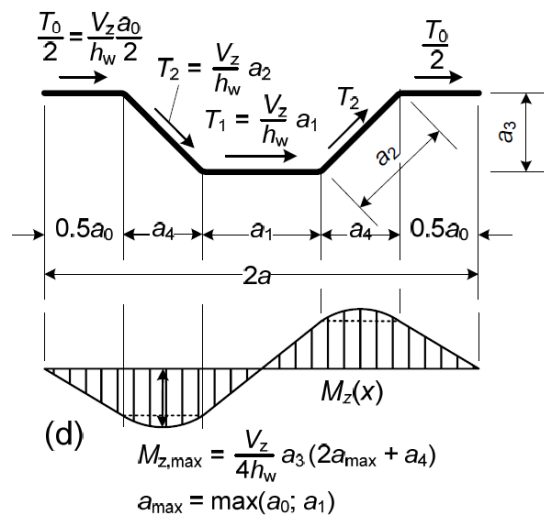


Fig. 7: Proposal to determine the additional bending moment [4].

2. Laboratory tests in Budapest

Laboratory tests were executed on 6 large scale test specimens with trapezoidally corrugated web at the Budapest University of Technology and Economics in 2008. The original aim of the tests was the investigation of the fatigue behaviour of the corrugated web girders, and to investigate the structural behaviour of the girders under static and dynamic loads. During the tests the stress distributions on different places in the flange and in the web were measured.

Two girders were loaded under four-point-bending and three specimens under three-point-bending. The main part of the strain measurements were made on the specimen loaded under four-point-bending and the stresses were measured in the constant bending moment zone, where the shear force was equal to zero. It was found that in this zone there was also a linear stress distribution between the two flange edges, what could come not from the shear flow in the corrugated web, it should have also an another reason. The measured stress distribution can be seen in Fig. 8. In the line of the parallel folds the normal stresses are smaller near to the web and larger far from it. The tendency of the stress distribution between the two flange edges is nearly linear and the difference changes between 18% - 27% in the cases of the analyzed girders.

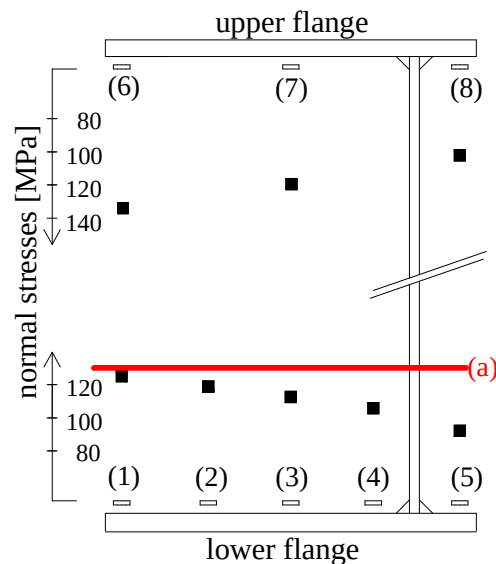


Fig. 8: Normal stress distribution in the flanges.

The reason of this phenomenon can be explained by the structural characteristic of the corrugated web. In the cross-section of the parallel folds the interlock between the upper and lower flanges are better than in the cross-section with an inclined fold. Therefore the web contribution in the load bearing is more dominant in the cross-section with a parallel fold than in a cross-section with inclined folds. This explanation is proved by the strain measurements in the web plate as well. The measured normal stress distribution in an inclined and in a parallel fold can be seen in Fig 9. The diagram shows the well known “accordion effect”. The diagram shows furthermore that the normal stresses in the inclined folds are smaller than in the parallel folds. The previous two establishments are in correlation with each other and it results in the difference in the normal stress distribution in the flanges.

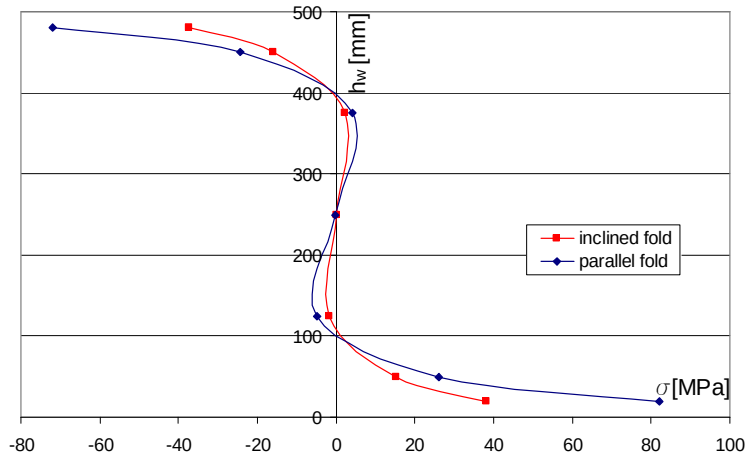


Fig. 9: Longitudinal normal stresses in the web along the depth.

The line (a) on Fig. 8 represents the calculated normal stress under the applied bending moment with the assumption that only the flanges are taken into account in the inertia calculation and the web part is neglected. This assumption is based on the “accordion effect” and the application of it is recommended by the EN1993-1-5. In the line of the inclined folds the normal stresses are approximately the same along the whole flange width in the constant bending moment zone and the stresses were just a little bit smaller than the calculated value represented by the line (a). It means that the measurements prove the assumption that the normal stresses in the flange of a corrugated web girders can be calculated neglecting the web part from the inertia calculation. The stresses in the cross-section with a parallel fold will be smaller near to the web but the largest stress can be determined using the above mentioned assumption. To determine the average stresses in the flange with a parallel fold an effective cross section with a small web part can be taken into account to get the average normal stress with adequate accuracy. The effective cross-section can be calculated based on the stress measurements and it is presented in Fig. 10. The effective web is the $\frac{3}{20}$ of the whole web depth for the girder with the analyzed geometry, but it is depending on the stiffness ratio of the flange and web plates and depends on the corrugation profile.

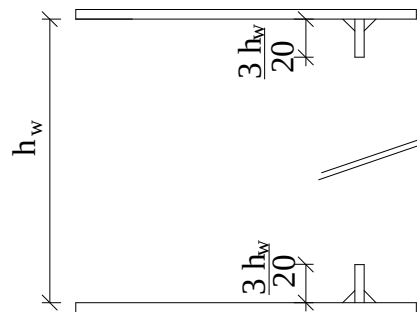


Fig. 10: Equivalent cross-section for the nominal stress calculation.

By summarizing the evaluation of the strain measurements in the constant bending moment zone the following conclusion can be drawn. The stress distribution in the cross-section with inclined fold is almost constant within the flange width. The stress distribution in the cross section with a parallel fold is nearly linear as shown in Fig. 8.

The measurements proved that the largest normal stress in a cross-section with inclined or parallel fold comes from pure bending can be determined by the assumption neglecting the web parts from the inertia calculation and the linear stress distribution comes not from an additional transverse bending but from the better interlock between the flange and web in the parallel fold region.

On the bases of these conclusions the stress distributions under combined shear and bending are investigated by a numerical model what is verified by the previously mentioned test results. The stress distribution is analyzed on the numerical model to investigate which proposed equation is more accurate in the prediction of the stress distribution of the corrugated web girders.

3. Numerical studies

The developed numerical model, the applied finite element mesh, the loading and support conditions can be seen in Fig 11.

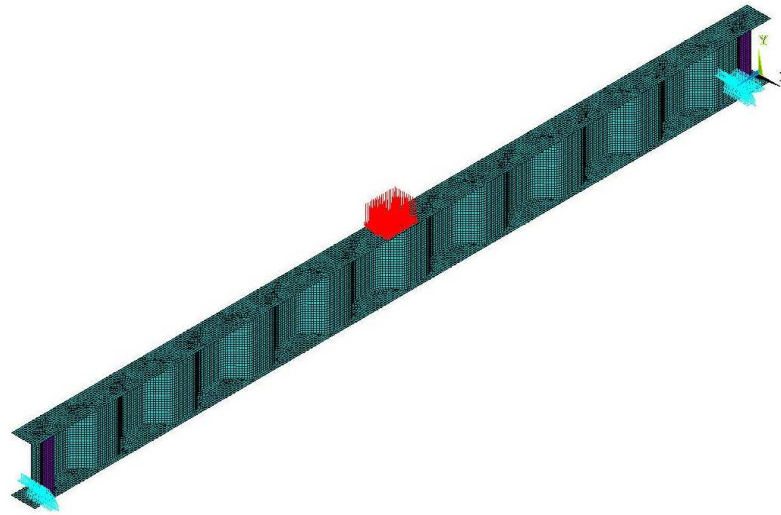


Fig. 11: Developed numerical model.

The numerical model is verified by the test results. The stresses in the flanges and in the web are compared. One comparison of the flange stresses can be seen in Fig 12.

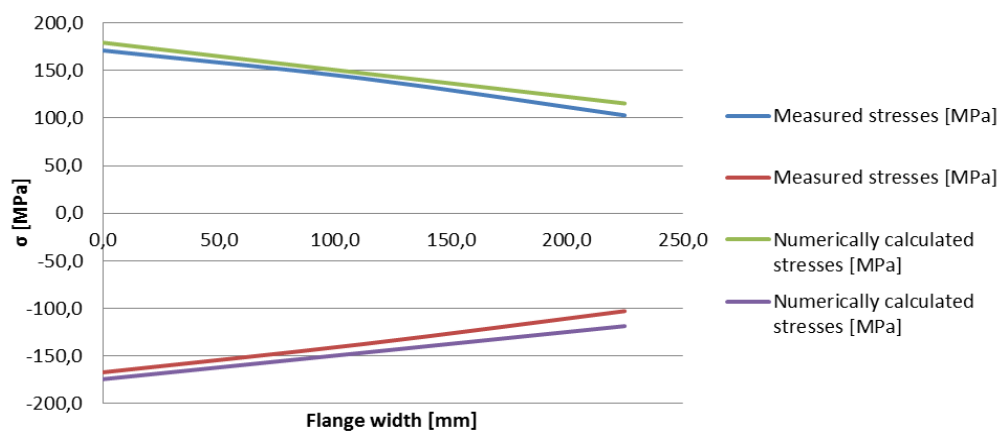


Fig. 12: Comparison of the measured and calculated stresses in the flange.

It can be seen that the comparison showed a good agreement between the test results and the numerical calculations.

In the frame of our numerical calculation the loading conditions shown in Fig. 13 are analysed.

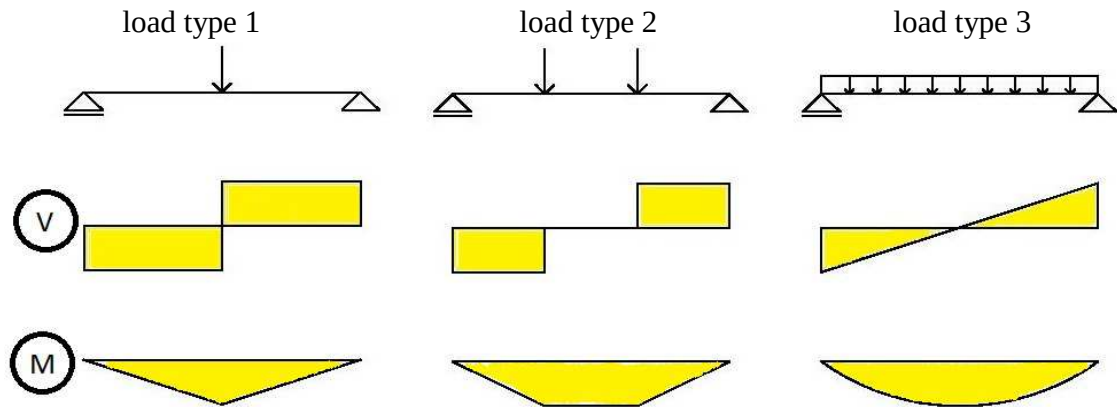


Fig. 13: Analyzed loading conditions.

Load type 1 is used to analyse the stress distribution under combined bending and shear. The results of the numerical calculations are compared to the proposed calculation methods of the additional transverse bending moments according to Aschinger and Lindner and according to the "Commentary to EN1993-1-5". The difference between the two proposals are analysed and evaluated.

Load type 2 is used to the model verification and to analyse the stress distribution in the flanges under pure bending. The above mentioned conclusions (1. stresses can be calculated neglecting the web parts, 2. the linear stress distribution comes not from additional transverse bending moment but from the bettwe interlock between the flange and web in the parallel fold regions) are proved and confirmed by the numerical calculations.

Load type 3 is used to investigate the effect of the loading condition on the additional transverse moment. According to the proposal of Aschinger and Lindner the value of the additional transverses bending moment changes between the load type 1 and 3, and according to the proposal of the "Commentary to EN1993-1-5" the additional bending moment depends only on the current shear force in the analysed cross section and not on the loading type.

4. Normal stress distribution in the flanges from load type 1

The stress distribution in the flanges in the middle of each web folds along the whole girder length are investigated and evaluated. The lines where the normal stresses are analyzed in the current research are shown in Fig. 14.

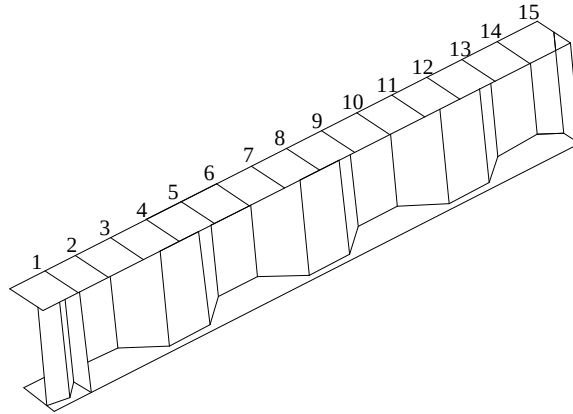


Fig. 14: Sections where the normal stresses are analyzed.

The results showed that the stress distributions in a parallel fold and in an inclined fold are not constant as shown in Fig. 15. The numerical calculation showed that there are also additional moments at the middle of the parallel fold as well.

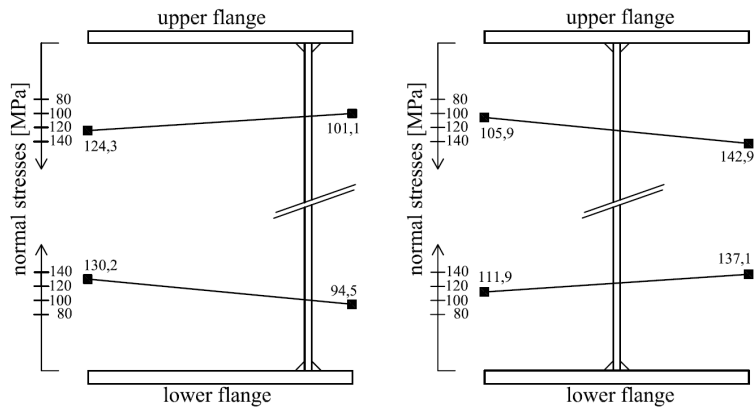


Fig. 15: Stress distribution in a parallel and in an inclined fold.

The assumption used in the derivation of the additional bending moment (Fig. 7) shows, that the additional bending moment at the middle of the parallel fold should be zero, but the numerical calculations do not confirm it.

Therefore the reason of it is investigated by us. It is observed that the tendency of the normal stress distribution in the flanges depends on the analyzed specimen geometry (number of the corrugation waves), and on the position of the load introduction place and on the support position. Four different loading and support positions can be identified:

1. Support at the middle of a parallel fold; loading at the middle of a parallel fold; not full corrugation waves between the support and loading place.
2. Support at the middle of a parallel fold; loading at the middle of a parallel fold; full corrugation waves between the support and loading place.
3. Support at the middle of an inclined fold; loading at the middle of an inclined fold; not full corrugation waves between the support and loading place.
4. Support at the middle of an inclined fold; loading at the middle of an inclined fold; full corrugation waves between the support and loading place.

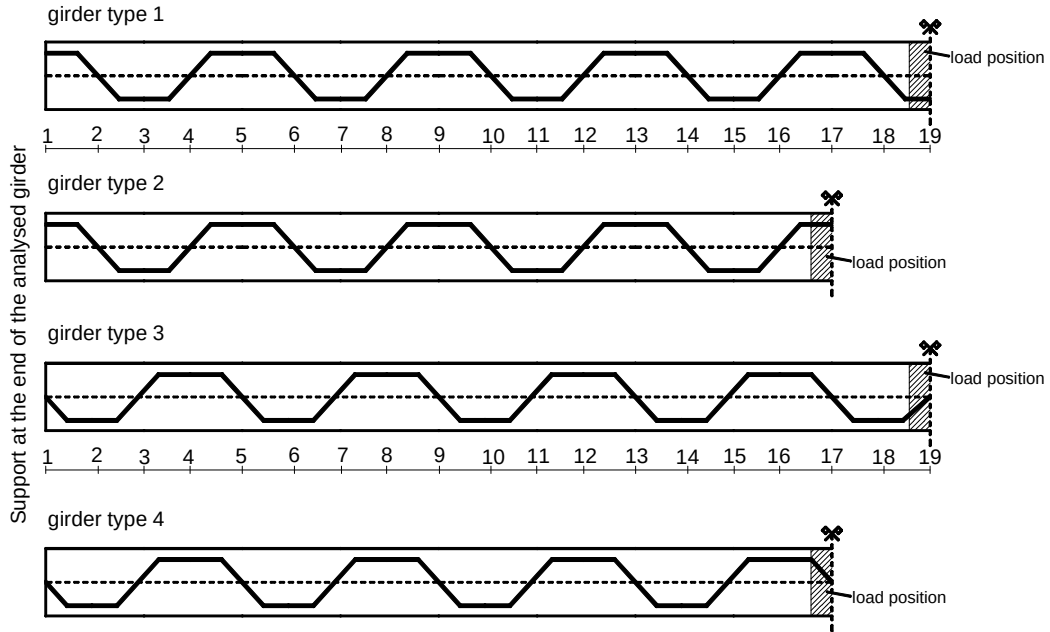


Fig. 16: Analysed girder geometries, support and loading positions (girder Nr. 1-4).

The numerical calculations showed that in the cases of the first two girder geometries, the stress distribution tendencies are the same as shown in Fig. 17. It means that the number of the modelled corrugation waves has no influence on the additional flange stresses. The position of the maximal additional normal stresses are located in the middle of an inclined fold (point Nr. 2, 4, 6, 8, etc.), and the values of the extrem points are constant along the girder length, because the shear force diagram is also constant. The additional bending moment has an alternating tendency, in the first parallel fold its direction is positive and in the next fold negative. The diagram shows that the stress differences in the middle of the parallel folds are always zero. It means that the diagram shows the same tendency as shown in Fig. 17.

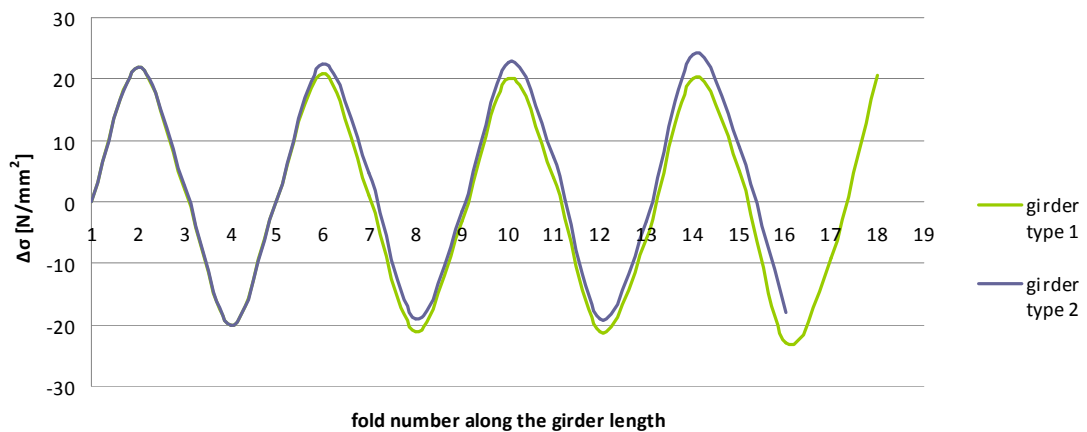


Fig. 17: Normal stress differences in the different cross-sections, tendency of the additional transverse bending moment along the girder length.

The differences between the two flange edges according to the "Commentary of EN1993-1-5" is calculated.

$$M_{z,\max} = \frac{V}{h_w} \cdot \frac{a_3}{4} (2a_1 + a_4) = \frac{50kN}{50cm} \cdot \frac{13,3cm}{4} \cdot (2 \cdot 21cm + 16,7cm) = 194,5kNcm \quad (3)$$

$$I_{z, flange} = \frac{22,5^3 \cdot 2}{12} = 1898,43cm^4 \quad (4)$$

$$\Delta\sigma = \frac{194,5}{1898,43} \cdot 22,5 = 23,1MPa \quad (5)$$

The numerical calculation resulted in 22,5 MPa, it means that the proposed equation gives a good prediction in the above mentioned loading and supporting conditions (support at the middle of a parallel fold; loading at the middle of a parallel fold).

But the numerical calculation showed that in the cases of the analysed girder type 3-4 the stress distribution tendencies are different, as shown in Fig 18.

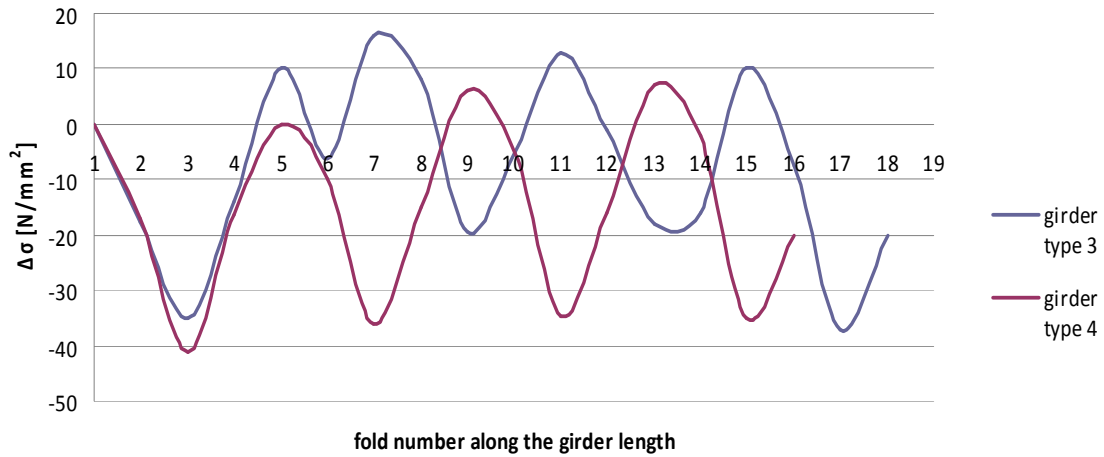


Fig. 18: Normal stress differences in the different cross sections, tendency of the additional transverse bending moment along the girder length.

The red curve shows the tendency of the additional transverse bending moment distribution along the girder length if support and load introduction places are located at the middle of an inclined fold and the girder has a number of full corrugation waves between the support and loading positions. It can be seen, that the tendency of the diagram is totally different from the tendency shown in Fig. 16. The transverse bending moment has not an alternating tendency, the minimum value is near to zero, and the maximum value (41,2MPa) is almost the double of the above mentioned maximum (22,5MPa). Evaluation of this diagram shows, that minimum and maximum values are always in the middle of the inclined fold and the transverse bending moments are not zero in the middle of the parallel folds. The diagram shows also that the maximum and minimum values are almost constant along the girder length, what can be explained by the full number of the corrugation waves. This is not the case for the analyzed girder type 3. The analyzed number of the corrugation waves here are not round and it results in a non-uniform tendency in the additional transverse moment diagram. The maximum value is located at the girder end and almost reaches the maximum of girder type 4. The

bending moment in the another folds are much smaller. The reason of it is the unbalanced shear forces in the corrugated web.

If the flange is handled as a beam loaded by bending, shear and normal forces coming from the shear force (as handled in [2] and [5]) the girder is only in equilibrium if the web begins with an inclined fold and ends also with inclined fold and between the two ends there are full number of corrugation waves. The equilibrium can be seen from the Fig. 19 (reaction forces $A=0$; $C=0$).

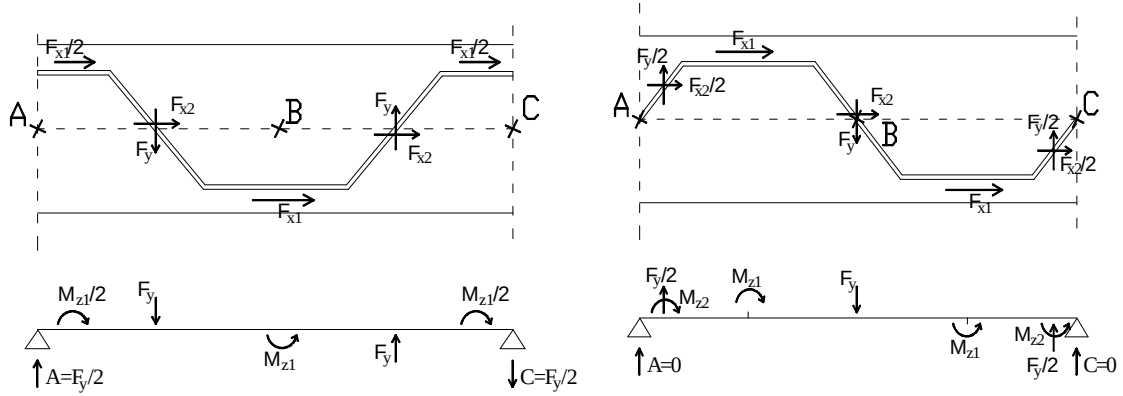


Fig. 19: Internal forces in different corrugation profiles.

The above mentioned diagram and result shows that the most unfavourable girder geometry, loading and support condition from the point of view of the additional transverse bending moment is the girder type 4. The transverse bending moment has the largest value in case of this geometry. The numerical calculations showed that the value of the additional transverse bending moment can be the double of the given equation in the [1] in the most unfavourable case. Therefore the Eq. (3) should be modified to Eq. (5).

$$M_{z,\max} = \frac{V}{h_w} \frac{a_3}{2} (2a_1 + a_4) \quad (6)$$

This formula can be derived from the shear stress distribution shown in Fig. 19. The same procedure can be done as by Prof. Balaž in [5] according to Fig. 7, but for the most unfavourable situation. The bending moment on point B can be written in form of Eq. (7).

$$M_{z,\max} = \frac{V}{h_w} a_1 \frac{a_3}{2} + 2 \frac{V}{h_w} \frac{a_4}{2} \frac{a_3}{4} + \frac{V}{h_w} \frac{a_3}{2} (a_1 + \frac{3a_4}{4}) - \frac{V}{h_w} \frac{a_3}{2} \frac{a_4}{4} \quad (7)$$

what can be simplified to the form of Eq. (8):

$$M_{z,\max} = \frac{V}{h_w} \frac{a_3}{2} (2a_1 + a_4) \quad (8)$$

Furthermore it can be enounced that the average value in the most unfavourable case can be calculated by Eq. (3) and the extreme value can be calculated by Eq (6).

The additional bending moment can be calculated according to the proposal of Aschinger and Lindner [2] as well. The applied load is a concentrated force, therefore the C_1 and C_2

values have the following values: $C_1=13$; $C_2=1,5$ according to Table 1. The additional moment can be calculated from Eq. (9).

$$M_{z1} = 13F_y + 1,5M_1 = 13\frac{V}{h_w}a_3 + 1,5\frac{V}{h_w}a_1\frac{a_3}{2} = 382,45kNcm \quad (9)$$

$$I_{z, flange} = \frac{22,5^3 \cdot 2}{12} = 1898,43cm^4 \quad (10)$$

$$\Delta\sigma = \frac{382,45}{1898,43} \cdot 22,5 = 45,3MPa \quad (11)$$

The calculated stress difference between the two flange edges according to [2] is 45,2 MPa, what is near to the numerically calculated value (41 MPa) and it is on the safe side.

In the frame of a numerical parametric study the influence of the different girder geometries on the maximal transverse bending moment are also analyzed. The calculations are executed always in the most unfavourable situation (girder type 4). The stress distributions in the inclined folds are determined at the girder end and at the girder middle near to the support and near to the load introduction places, where the maximum value of the transverse bending moment occur. The tendencies of the different parameters can be seen in Figs. 20- 24.

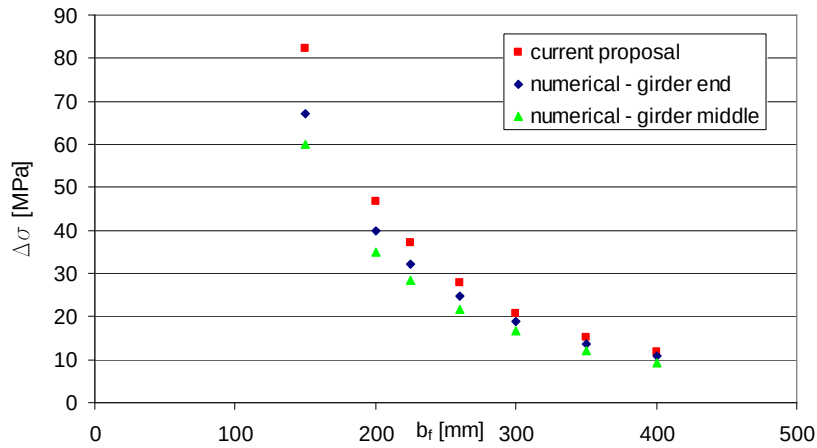


Fig. 20: Effect of the flange width.

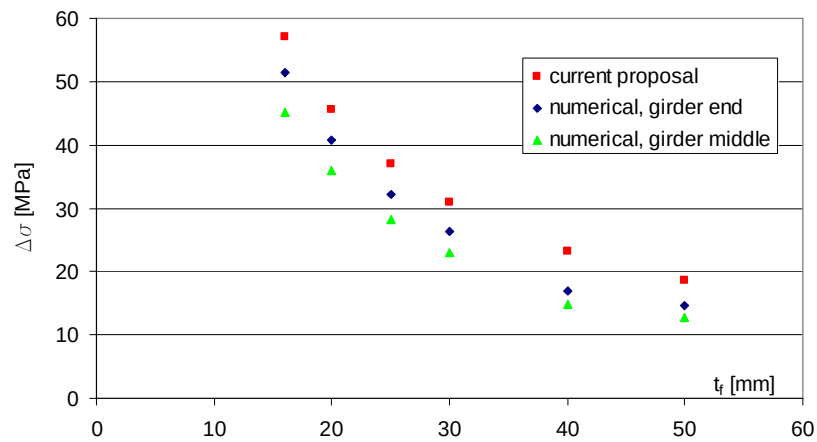


Fig. 21: Effect of the flange thickness.

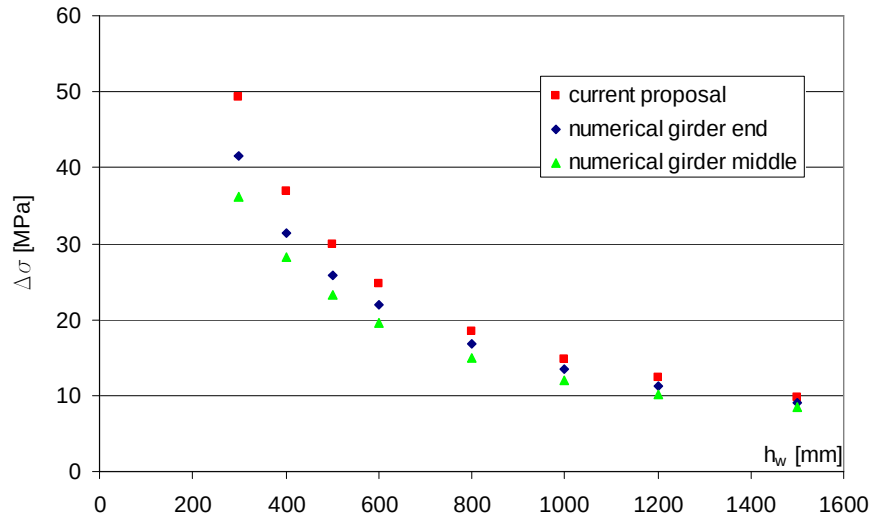


Fig. 22: Effect of the web depth.

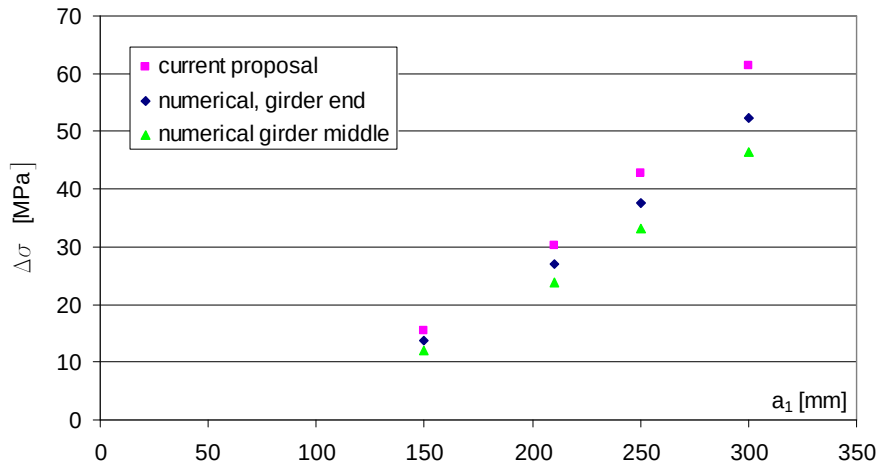


Fig. 23: Effect of the fold length.

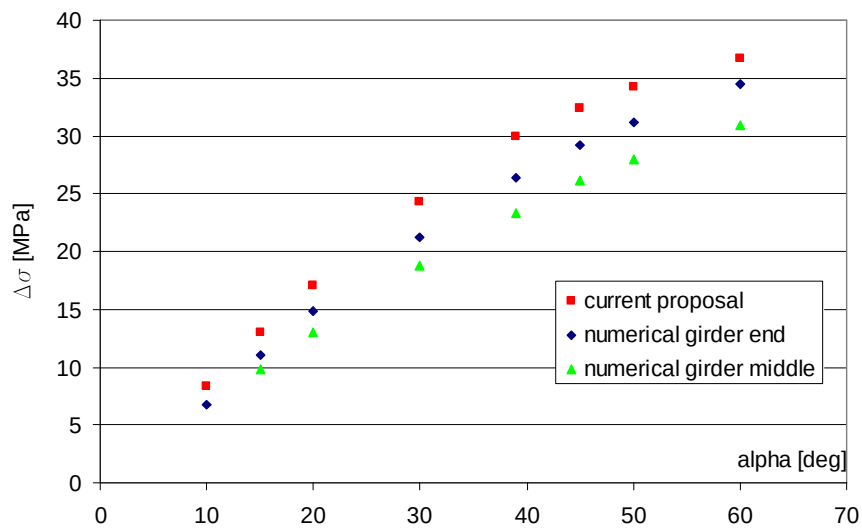


Fig. 24: Effect of the corrugation profile.

The numerical parametric study showed that with increasing flange width or thickness the additional normal stresses are smaller in the flange plate. By increasing web depth the shear stresses also reduces, therefore the additional transverse moment and the additional normal stresses are also smaller. But if the corrugation angle or the fold length of the corrugated web increases, the shear flow results in a larger transverse moment, what indicates larger additional normal stresses. The diagram shows that the tendencies found in the numerical parametric study are the same as the tendency of the modified transverse bending moment determination method, according to Eq. (6). It proves the applied theoretical background.

The results of the numerical calculations are compared to the proposal of Aschinger and Lindner [2] and to the proposal of the "Commentary to EN1993-1-5" [1]. The diagram can be seen in Fig. 25.

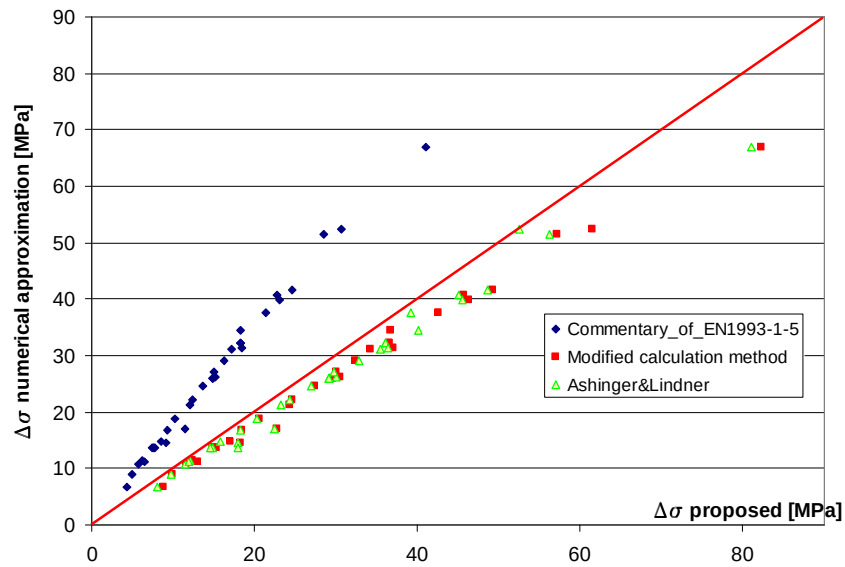


Fig. 25: Comparison of the different design proposals for load type 1.

Based on this results the maximum additional stress in the flange coming from the shear stresses in the corrugated web can be determined using the proposal of Aschinger and Lindner [2] or by the modified equation according to Eq. (6), if the applied load is a concentrated force, what means that the shear force diagram along the girder length is constant. The application of the original form of the "Commentary to EN1993-1-5" [1] (Eq. 3) results in values on the unsafe side in the analyzed cases.

It is observed that the proposal of Ashinger and Lindner [2] does not follow the tendencies of the numerical calculations if the lengths of the parallel and inclined folds are different ($a_1 \neq a_2$). Figure 26 shows the additional normal stresses in function of the a_2 by constant a_1 . The diagram shows that the current modification proposal follows the calculated tendencies in the analyzed parameter range, but the proposal of Aschinger and Lindner [2] has not the same tendency and the values are not in all cases on the safe side.

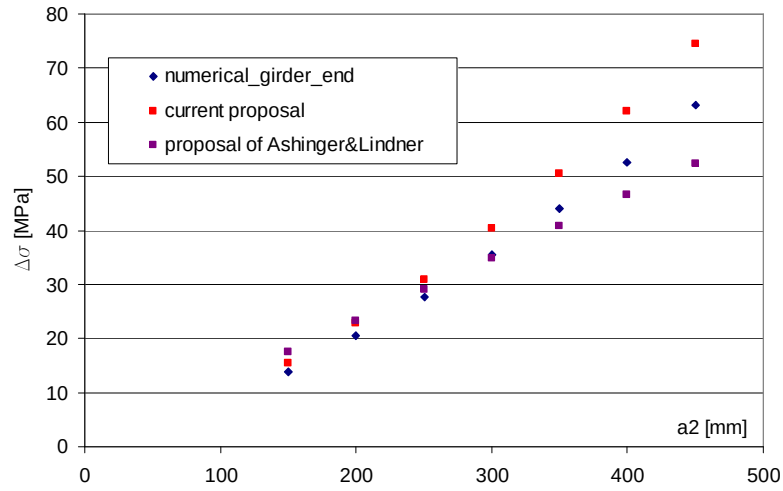


Fig. 26: Effect of the different fold lengths.

The comparison of the numerical results and the calculated values according to the different design proposals is shown in Fig. 27.

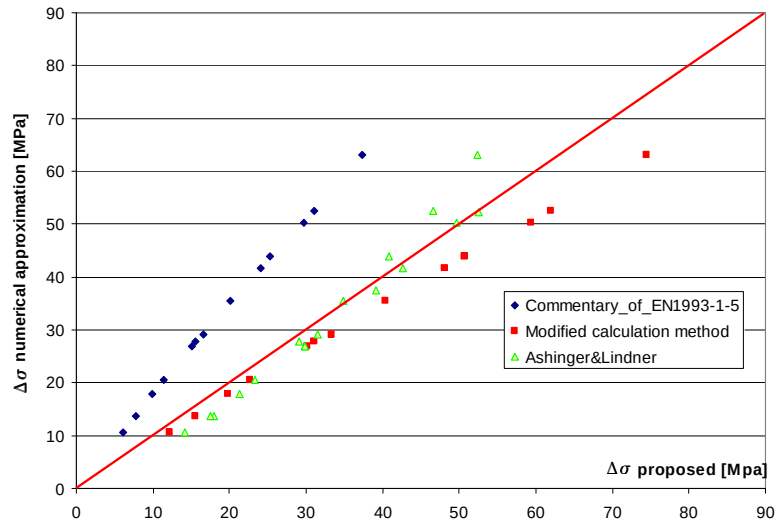


Fig. 27: Comparison of the different design proposals.

If the loading type is different from the above mentioned, the proposal of Aschinger and Lindner [2] changes (C_1 and C_2 values changes), but the proposal of the "Commentary to EN1993-1-5" does not change, only in the value of the shear force. Therefore in the next section the normal stress distributions under uniformly distributed load are analyzed.

5. Normal stress distribution in the flanges from Load type 2

The calculations are executed in the most unfavourable loading and supporting conditions (girder type 4), because the largest additional transverse moment is observed in this case. The results of the numerical calculations can be seen for one girder in Fig. 28. The uniform change in the shear force diagram can be observed also in the diagram of the transverse bending moment. The maximum values of the diagram changes along the girder length nearly linearly. This observation suggest, that the additional normal stresses

coming from the transverse bending moment could be calculated in each cross-section from the shear force acting in the analyzed cross-section. This assumption results in values always on the safe side.

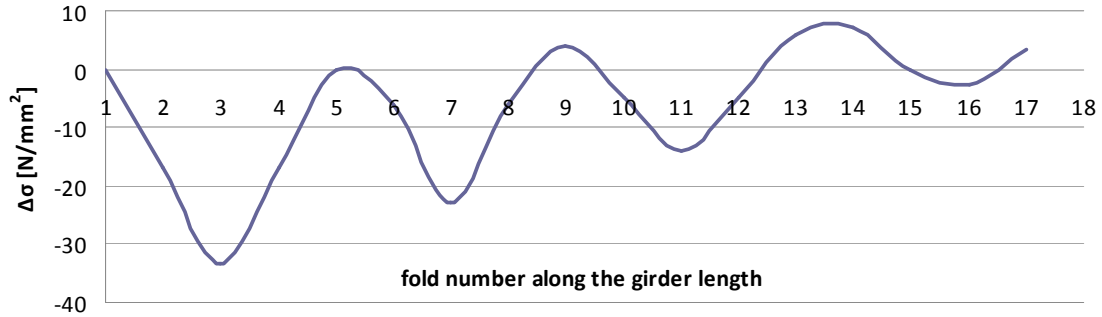


Fig. 28: Normal stress differences in the different cross-sections, tendency of the additional transverse bending moment along the girder length.

The same parametric study is executed in the case of load type 2. The results can be seen in Fig. 29. The diagram shows that the proposal of Aschinger and Lindner [2] is not in all cases on the safe side in case of a uniformly distributed load, if the shear forces acting in the analyzed cross-section are taken into account in the calculation of the additional normal stresses. But the results of the modified equation remain in all cases on the safe side.

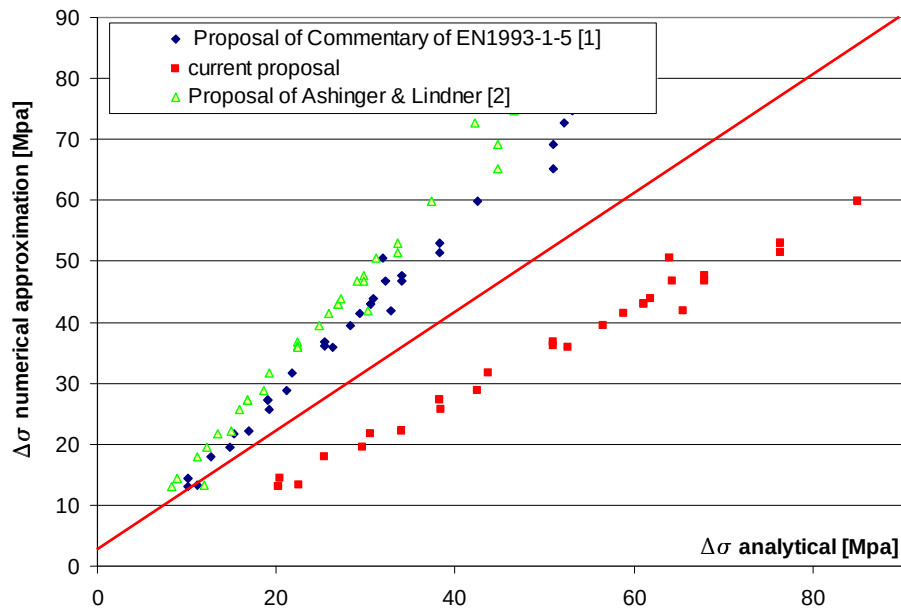


Fig. 29: Comparison of the different design proposals for load type 2.

6. Conclusions

The recent report focuses on the stress distributions in the flange of the corrugated web girders. The different design proposals found in the literature are studied and compared to each other. The stress distribution in the flange of the corrugated web girders are analyzed under different loading and supporting conditions numerical and experimental.

The previous design methods are compared to the numerical calculations and as a result the following conclusions can be drawn:

1. The test results showed that the stress distribution under pure bending in a cross-section with inclined fold is almost constant within the flange width, and in a cross section with a parallel fold is nearly linear. The measurements proved that the largest normal stress in a cross-section of a corrugated web girder under pure bending can be determined by the assumption neglecting the web part from the inertia calculation.
2. Numerical calculations showed that the normal stress distribution in the flange under combined bending and shear depends on the analyzed specimen geometry (number of the corrugation waves), on the position of the load introduction place and on the support position. The result shows that the most unfavourable girder geometry, loading and support condition from the point of view of the additional transverse bending moment is the girder type 4. The largest transverse bending moment is calculated in case of this geometry, loading and supporting conditions.
3. Analyzing the most unfavourable case the numerical calculations showed that the value of the additional transverse bending moment can be the double of the given equation in [1] and [5] in the most unfavourable case. Therefore a new design equation is derived and proposed to determine the maximum transverse bending moment. Furthermore it can be enounced that the average value in the most unfavourable case can be calculated by the proposal of [1] and [5] and the extreme value can be calculated by the current proposal.

$$M_{z,\max} = \frac{V}{h_w} \frac{a_3}{2} (2a_1 + a_4)$$

4. The numerical calculations show that the maximum additional transverse bending moment can be calculated according to the proposal of Aschinger and Lindner [2] as well, if the shear force diagram along the girder length is constant. But the recent calculations showed that this design proposal should be not used if the shear force diagram is not constant, or the fold lengths (a_1 and a_2) of the corrugation profile are not the same.
5. The calculations show that the proposal in [1] and [5] follows the tendencies of the numerical parametric study in the analyzed parameter range. It proves that the theoretical background of the calculation method is correct, but the results are not in all cases on the safe side. The new proposal follows also the tendencies in the analyzed parameter range and it gives a safe side result in all loading and supporting conditions.
6. The proposal in [3] and [4] is complex and takes the torsion effect of the corrugated web girders into account. The maximum transverse bending moment can be also determined according to the proposed “fictitious load method”, but due to its complexity and difficulty, the application of it in the praxis is not recommended.