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BEHAVIOUR OF BOX-GIRDER UNDER ANTISYMMETRICAL ACTION

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Abstract: *Steel experimental trapezoidal box-girder loaded by two pairs of antisymmetrical transverse forces. Torsional and distortional cross-section properties of exact and simplified models of cross-section. Internal forces of torsion and distortion calculated by analogy with bending. Solutions of difficult torsion and distortion problems using analogies with solutions of simple bending problems describe behaviour of box-girder in well understandable form. Comparison of experimental stresses with theoretical ones.*

Keywords: Steel, box-girder, torsion, distortion, analogies

1. Introduction

The set up of loading frame is described in (Baláž et al, 2016). The trapezoidal cross-section and 9 transverse stiffening frames of 8.4 m long experimental box-girder are in Fig. 1 and Fig. 2.

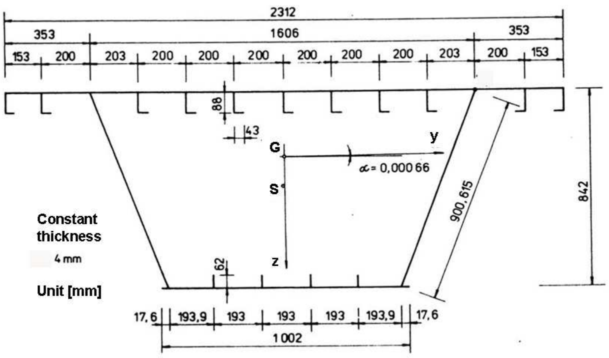

Fig. 1: Box-girder cross-section

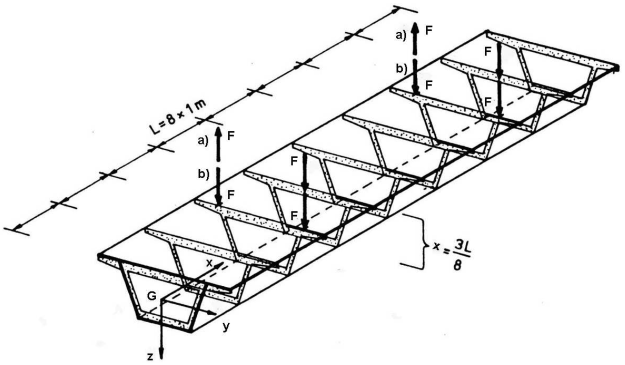

Fig. 2: Experimental box-girder in normal position

Dimensions of parts of transverse stiffening frame are as follows: a) transverse stiffener of upper wide flange: 167 mm x 4 mm, b) transverse stiffener of girder webs: 80 mm x 4 mm, c) transverse stiffener of bottom narrow flange: 120 mm x 4 mm. The transverse stiffening frames at the girder ends and in the cross-sections of the load application were strengthened by diaphragm with opening dimensions: height h = 551 mm (between edges of upper and bottom transverse stiffeners) and width b = 440 mm.

The box-girder was loaded by 2 pairs of antisymmetrically arranged transverse forces F (case a) in Fig. 2) and by 4 symmetrically arranged transverse forces F (case b) in Fig. 2). In this paper only the case a) is described. Antisymmetrical loading required another strengthening in the form of plate stiffened by vertical stiffeners added to the box-girder from its outer side (see section A-A in Fig. 12). It enables to introduce the left forces in Fig. 2 a) from girder bottom side and to keep distance of pair of hydraulic jacks in transverse direction 1606 mm (Fig. 10) as it was in the case of symmetrical loading (Fig. 2 b). The maximum capacity of each of 4 hydraulic jacks was 500 kN.

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The strains and stresses were evaluated in 204 points with the help of the logger TSA-63. The deformations were measured with the exactness 0,1 mm in the sections 0, L/8, L/2, 3L/8 and L.

The 5 tests were performed in the following order in which the box-girder was under: 1) verification symmetrical loading, 2) the first antisymmetrical loading, 3) the second antisymmetrical loading, 4) symmetrical loading of girder in normal position, 5) symmetrical loading of girder in reverse position.

2. Experimental tests

During verification symmetrical test the local crushing of the bottom part of inclined girder web occurred at movable support (Fig. 4). Therefore the edge of diaphragm at support was strengthened by vertical L-profiles (see Fig. 5 in Baláž et al (2016)).

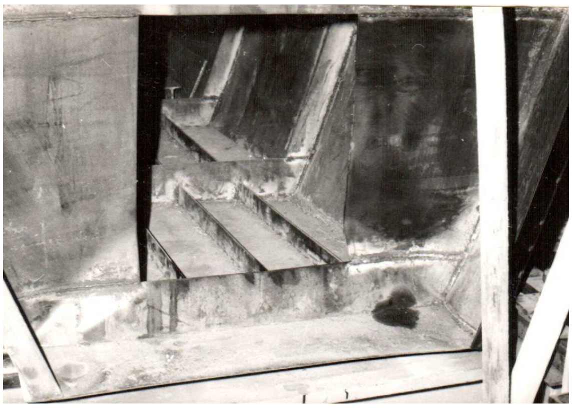

Fig. 3: Diaphragm at the box-girder end

Fig. 4: Local crushing of the web at support

The following phenomena were investigated during antisymmetrical loading (Baláž, 1980):

1. distribution of direct stresses in longitudinal direction in three box-girder cross-sections;
2. distribution of direct stresses in two transverse stiffening frames;
3. twisting and distortion of five box-girder cross-sections under antisymmetrical loading.

The strains and displacements were measured in the chosen points for the following values of transverse forces *F* (Fig. 2 a) during (i) the first antisymmetrical loading: *F* = 0 kN – 100 kN – 0 kN – 100 kN – 150 kN – 200 kN and (ii) the second antisymmetrical loading: *F* = 0 kN – 100 kN – 0 kN – 150 kN – 200 kN – 0 – 250 kN – 300 kN. The further increasing of transverse forces *F* was limited by tension resistance of anchorage bolts. The weakest place was located in the right bottom edge of the transverse stiffening frame where the local plastification occurred.

Comparisons of experimental values of direct stresses with theoretical ones are given and evaluated in paragraph 4. Distributions of direct stresses σ_x in three sections 1.5L/8, 2.52L/8, 3.5L/8 are shown in Fig. 11. Distributions of direct stresses σ_{sD} in transverse direction due to distortion in transverse stiffening frame in two sections x = 2L/8 and 3L/8 may be seen in Fig. 12.

Deformations were measured in five sections: 0, L/8, L/2, 7L/8, L. Figs. 5 and 6 show deformations measured in the middle of the span during 1st and 2nd antisymmetrical loadings.

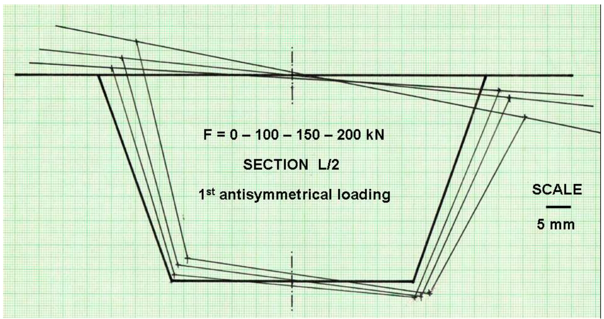

Fig. 5: Deformations in section L/2 measured in 1st antisymmetrical loading

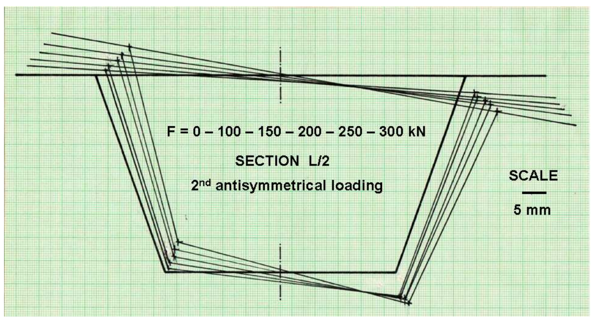

Fig. 6: Deformations in section L/2 measured in 1st antisymmetrical loading

3. Theoretical results

The distributions of the torsional bimoment and distortional bimoment are on Fig. 7 and Fig. 8.

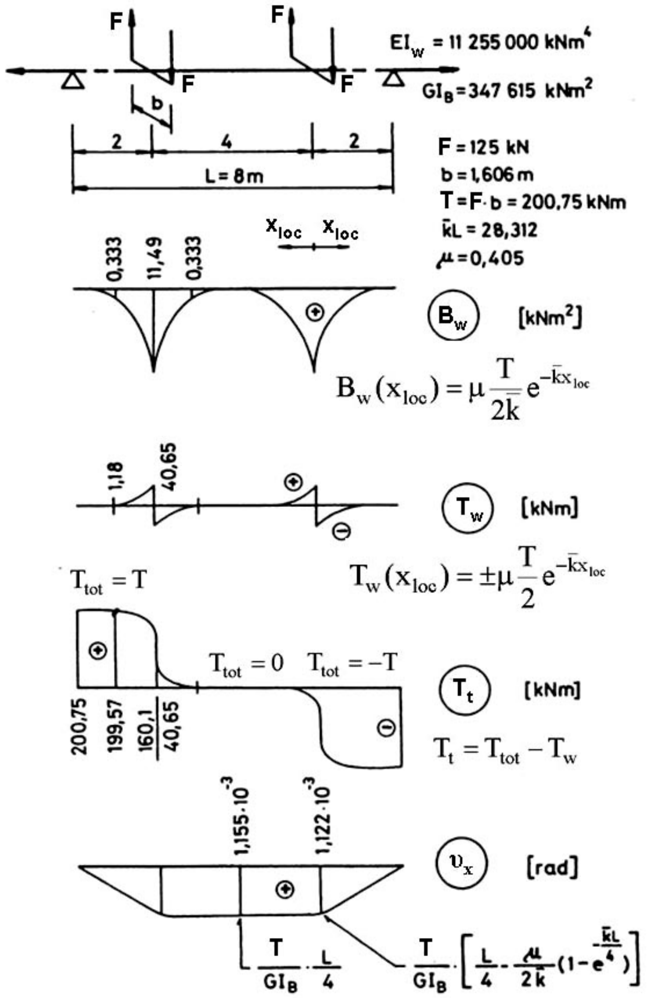

Fig. 7: Internal forces of torsion with taking into account the influence of the shear. The formulae are valid for "infinite long" beam on both ends

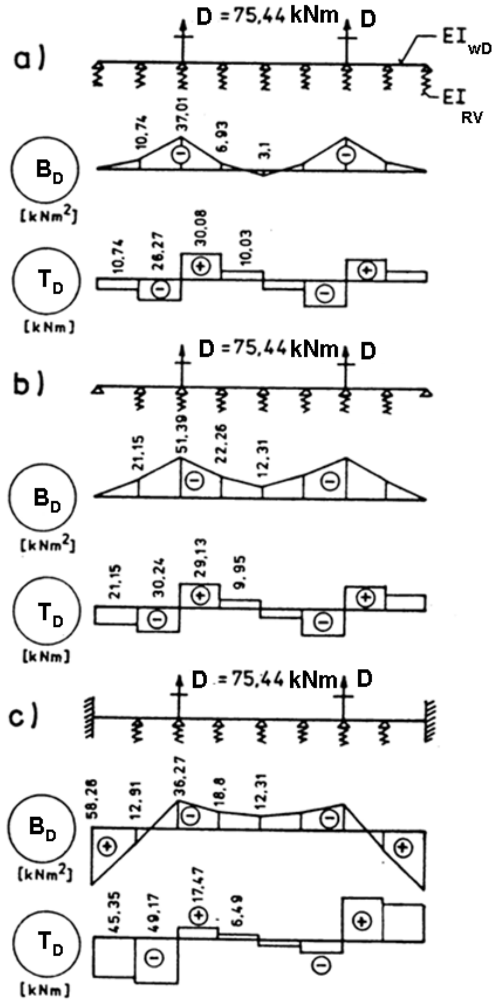

Fig. 8: Internal forces of distortion on the beam with the ends: a) on the elastic springs, b) simply supported, c) fixed

Details of calculation of cross-sectional properties of distortion and torsion are given in (Baláž, Agócs, 1994). Details of calculation of internal forces, direct and shear stresses are given in (Baláž, 2004). Theoretical results given here are valid for F = 125 kN. They may be used for any value of F by multiplying F / 125 kN.

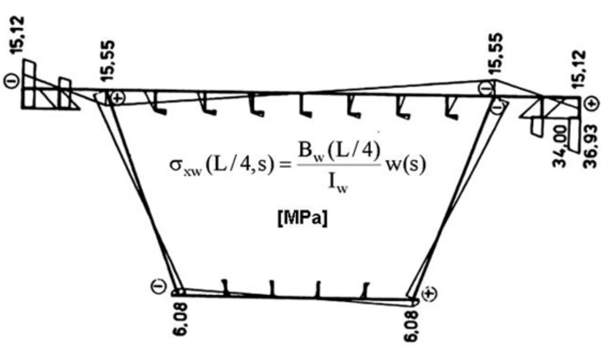

Fig. 9: Torsion direct stresses due to F = 125kN

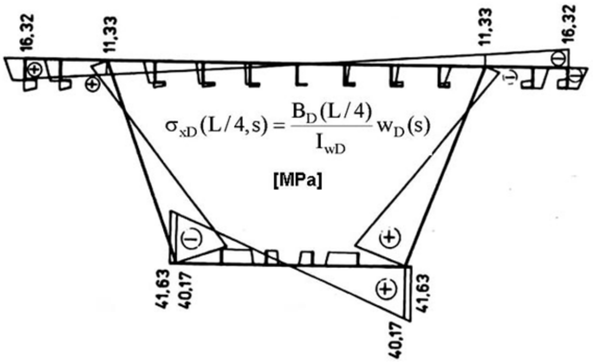

Fig. 10: Distortion stresses due to F = 125kN

4. Comparison of experimental and theoretical values and conclusions

The experimental and theoretical results show that transverse stiffening was relatively weak and therefore direct stresses due to cross-section distortion (Fig. 10) are greater than those due to torsion (Fig. 9). On the axis of symmetry the theoretical direct stresses due to antisymmetrical loading (Fig. 2 a) are zero (Fig. 9, Fig. 10) . This is not true for the experimentally measured values of direct stresses (Fig. 11).

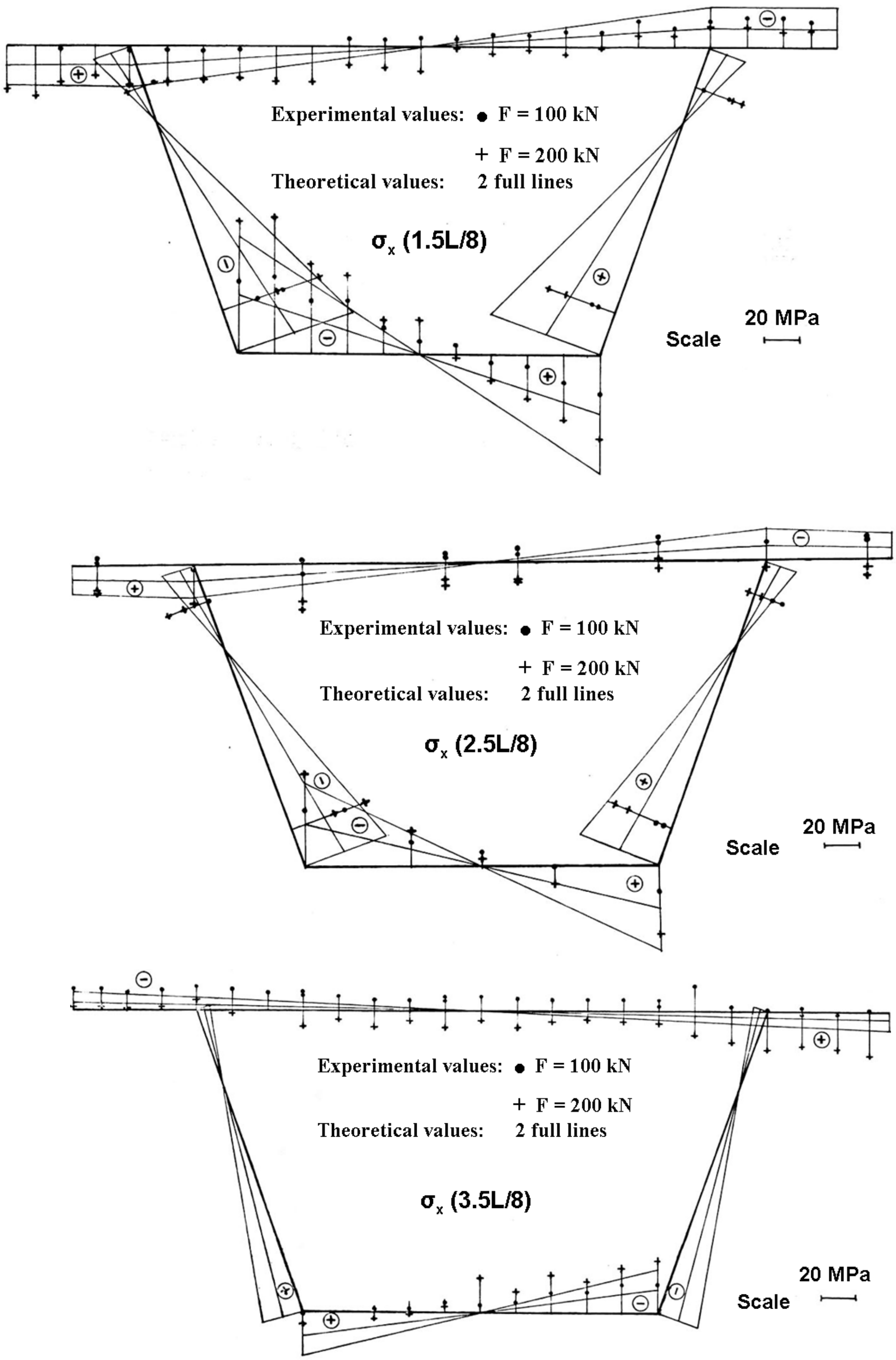

Fig. 11: Graphical comparison of experimental and theoretical values of direct stress σ_x in longitudinal direction due to distortion and torsion in three sections x = 1.5L/8, 2.5L/8, 3.5L/8

The reasons are: a) the experimental beam was at the ends elastically supported in torsion, b) it was necessary to weld additive transverse stiffener outside of cross-section in sections 2L/8 and 6L/8 only on the left side to enable to load the trapezoidal cross-section of the box-girder by the left hydraulic jacks from bottom side (Fig. 12). These two reasons are responsible for not perfectly antisymmetrical distribution of experimental direct stresses (Fig. 11).

Distortional bimoment B_D changes the sign along the box-girder length (Fig. 8). The same phenomenon may be seen in distribution of experimental direct stresses: compare direct stresses in sections 2.5L/8 with those in section 3.5L/8 (Fig. 9).

Theoretical direct stresses in transverse stiffening frames are greater than experimental ones (Fig. 12). The comparison of theoretical and experimental values shows, that behaviour of experimental box-girder loaded by antisymmetrical loading may be described by the values obtained by hand calculation based on analogies with beam in bending (Fig. 7 and 8).

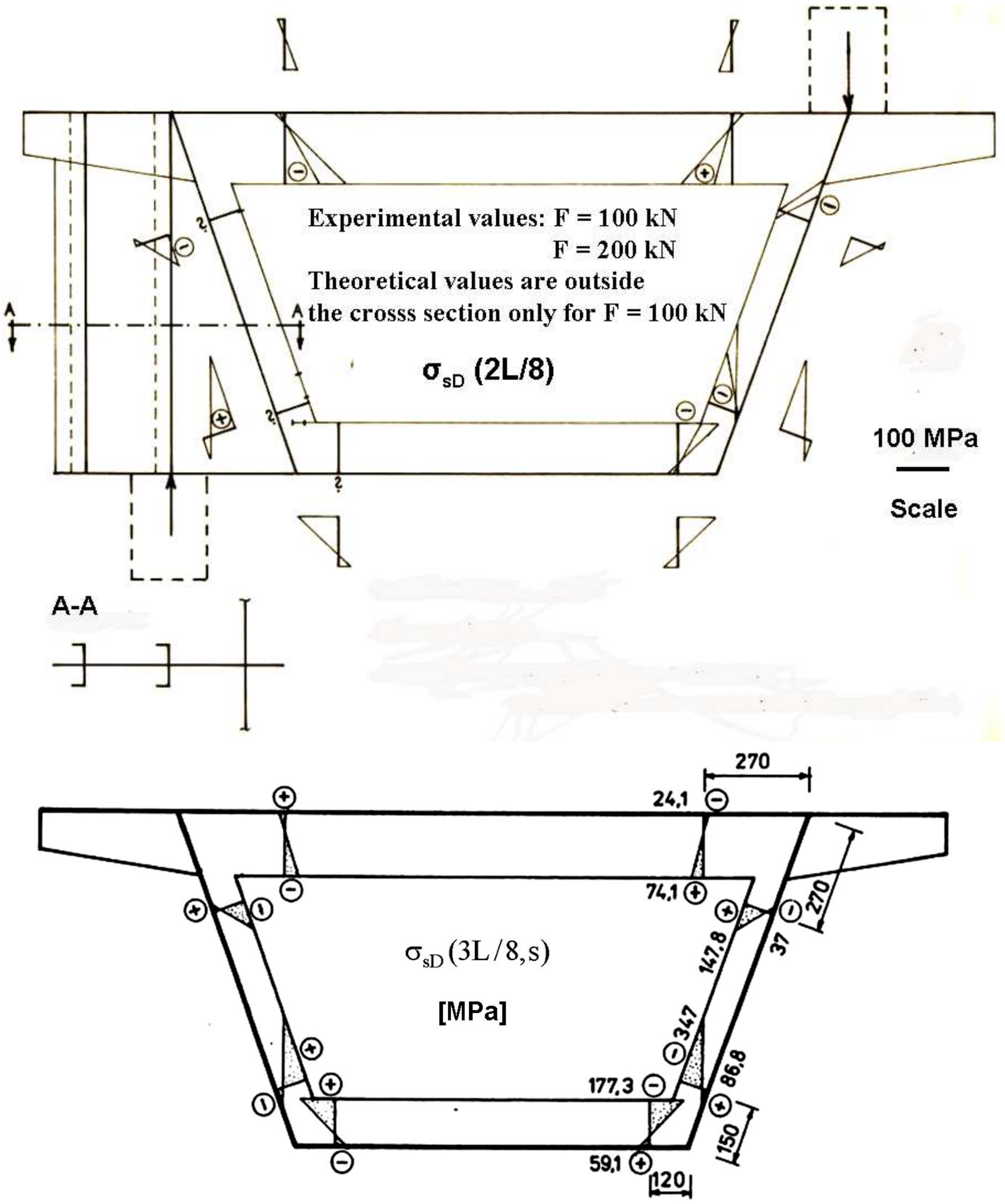

Fig. 12: Graphical comparison of experimental and theoretical values of direct stress σ_{sD} in transverse direction due to distortion in transverse stiffening frame in the sections x = 2L/8 and 3L/8

Acknowledgement

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