FEDERATION EUROPEENNE DE LA MANUTENTION
Section IX

SERIES LIFTING EQUIPMENT

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Local Girder Stresses

1 Local girder stresses

The flange bending stresses σ_{Fx} and σ_{Fz} arise as secondary stresses in the vicinity of the place of load application in a girder, regardless of its supporting structure (figure 1.1 and 1.2).

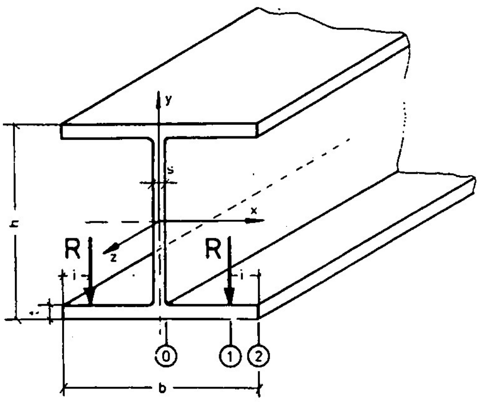


Figure 1.1 Parallel flange track section

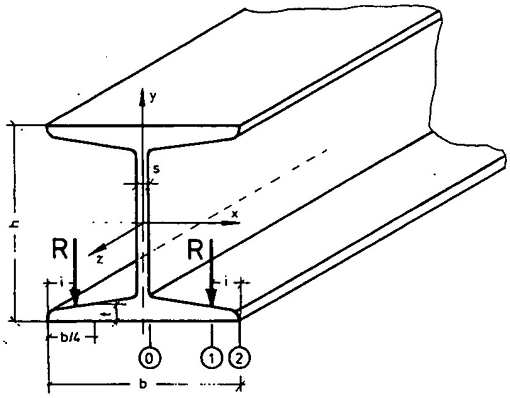


Figure 1.2 Girder with inclined flanges

The stresses are calculated with the help of the equations

$$\sigma_{Fx} = c_x \frac{R}{t_i^2}$$

$$\sigma_{Fz} = c_z \frac{R}{t_i^2}$$

The factors c_x and c_z used in the equations can be determined separately according to the type of girder (figure 1.1 and 1.2) and the load position i or λ for the specially marked points (0), (1), (2) on the flange.

The variables R, t_i, i and λ necessary for the stress computation have the following meanings:

- R represents the maximum wheel load ascertained upon consideration of the dynamic coefficients.
- t_i is the theoretical thickness of the flange at the load position i (without tolerances and wear).
- i is the distance from the girder edge to the point of load application.
- λ is calculated as the quotient from

$$\lambda = \frac{i}{\frac{b}{2} - \frac{s}{2}}$$

2 Determination of the coefficients c_x, c_z

The coefficients established here are based on numerous test results [1]. Theoretical investigations of certain test results with the method of finite elements have proved largely concurrent [1]. The equations listed below, which are the product of test results, are valid for the ascertainment of the coefficients c_x, c_z. Positive values of $c_{x/z}$ mean tensile stress on the bottom of the flange.

2.1 Parallel flange track section according to figure 1.1

Transition web/flange	$c_{z0} = 0{,}05 - 0{,}58 \cdot \lambda + 0{,}148 \cdot e^{3{,}015 \cdot \lambda}$	(1)
Load application point	$c_{z1} = 2{,}23 - 1{,}49 \cdot \lambda + 1{,}390 \cdot e^{-18{,}33 \cdot \lambda}$	(2)
Edge of the flange	$c_{z2} = 0{,}73 - 1{,}58 \cdot \lambda + 2{,}910 \cdot e^{-6{,}0 \cdot \lambda}$	(3)
Transition web/flange	$c_{x0} = -2{,}11 + 1{,}977 \cdot \lambda + 0{,}0076 \cdot e^{6{,}53 \cdot \lambda}$	(4)
Load application point	$c_{x1} = 10{,}108 - 7{,}408 \cdot \lambda - 10{,}108 \cdot e^{-1{,}364 \cdot \lambda}$	(5)
Edge of the flange	$c_{x2} = 0$	(6)

2.2 Girder with inclined flanges according to figure 1.2

Transition web/flange	$c_{z0} = -0{,}981 - 1{,}479 \cdot \lambda + 1{,}120 \cdot e^{1{,}322 \cdot \lambda}$	(7)
Load application point	$c_{z1} = 1{,}810 - 1{,}150 \cdot \lambda + 1{,}060 \cdot e^{-7{,}700 \cdot \lambda}$	(8)
Edge of the flange	$c_{z2} = 1{,}990 - 2{,}810 \cdot \lambda + 0{,}840 \cdot e^{-4{,}690 \cdot \lambda}$	(9)
Transition web/flange	$c_{x0} = -1{,}096 + 1{,}095 \cdot \lambda + 0{,}192 \cdot e^{-6{,}0 \cdot \lambda}$	(10)

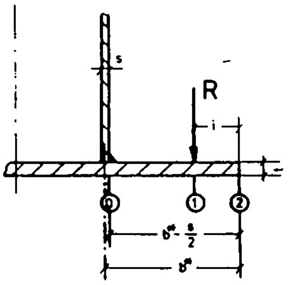
1) Hannover, H.-O. und Reichwald, R.: Lokale Biegebeanspruchung von Träger-Unterflanschen (Local flexural stressing of girder lower flanges), f+h-fördern und heben 32 (1982) Nr. 6 (Teil 1) und Nr. 8 (Teil 2)

Load application point $c_{x1} = 3{,}965 - 4{,}835 \cdot \lambda - 3{,}965 \cdot e^{-2{,}675 \cdot \lambda}$ (11)

Edge of the flange $c_{x2} = 0$ (12)

2.3 Lower chord of box type girder

The lower chord of a box type girder is to be calculated as a parallel flange track section. Figure 2 represents an analogous depiction.



$$\lambda = \frac{i}{b^* - \frac{s}{2}}$$

Figure 2. Lower chord of a box type girder

3 Ascertainment of stresses

The flange bending stresses σ_{Fz} are to be superimposed on the main stresses σ_{Hz} resulting from vertical and lateral forces. The flange bending stresses are diminished by the factor $\epsilon = 0.75$. This also holds true for the flange bending stresses to be considered for the proof of service strength.

$$\sigma_x = \epsilon \cdot \sigma_{Fx}$$

$$\sigma_z = \sigma_{Hz} + \epsilon \cdot \sigma_{Fz}$$

3.1 General proof of stress

In the case of composite plane stresses, the following must be proven with consideration of the signs

in structural parts:

$$\sigma_{cp} = \sqrt{\sigma_x^2 + \sigma_z^2 - \sigma_x \cdot \sigma_z + 3 \cdot \tau_{xz}^2} < \sigma_a$$

in welding seams:

$$\sigma_{cp} = \sqrt{\sigma_x^2 + \sigma_z^2 - \sigma_x \cdot \sigma_z + 2 \cdot \tau_{xz}^2} < \sigma_{aw}$$

3.2 Proof of service strength

$$\left(\frac{\sigma_{x\,max}}{\sigma_{xa}}\right)^2 + \left(\frac{\sigma_{z\,max}}{\sigma_{za}}\right)^2 - \frac{\sigma_{x\,max} \cdot \sigma_{z\,max}}{|\sigma_{xa}| \cdot |\sigma_{za}|} + \left(\frac{\tau_{xz\,max}}{\tau_{xza}}\right)^2 \leqslant 1{,}0^{*)}$$

Definitions:

$\sigma_{x\,max}$ $\sigma_{z\,max}$	calculated normal stress in the x and z directions
$\tau_{xz\,max}$	calculated shear stress
σ_{xa} σ_{za}	admissible normal stress corresponding to $\sigma_{x\,max}$ and $\sigma_{z\,max}$ stresses
$\lvert\sigma_{xa}\rvert$ $\lvert\sigma_{za}\rvert$	sum total of σ_{xa} and σ_{za}
τ_{xza}	admissible shear stress corresponding to the $\tau_{xz\,max}$ stress.

The equations in paragraphs 3.1 and 3.2 apply to cranes. Corresponding equations, to be taken from the respective national regulations, apply to crane runways or other steel structures.

4 Explanation of the design rules

Design rules are given for local flange bending stresses on rolled sections with inclined and parallel flanges. The design rules are based on the results of tests [1]). Measurements on the following sections were evaluated: I 200, I 300 as in DIN 1025 part 1 and IPE 200, 300, 360 as in DIN 1025 part 5. The load was distributed symmetrically along the longitudinal axes of the girders. The lower chord of box girders with an underrunning trolly should also be calculated using geometric characteristics with the equations for the parallel-flange girder.

The wheel load is ideally assumed to be a load point in the middle of the Hertzian surface. Tolerances in the thickness of the flange are not taken into account. Generally, no reduction in the flange thickness as a result of wear is to be taken into account. Results of tests on four overhead travelling cranes with underrunning trolleys after 14 years of operation have shown wear of less than 1 mm. Only on heavily stressed suspension tracks is it possibly necessary to increase the thickness of the section on account of wear (e. g. by 5 mm for a flange thickness of 30 mm).

When determining stresses, flange bending stresses should be superimposed with the main stresses from vertical and lateral forces both in the general stress proof and in the service strength proof (e. g. in a box girder lower chord). Thus for σ_{perm} it should be borne in mind that in crane girders there is a principal load picture with vertical load and lateral force. In superimposing flange bending stresses on principal stresses, the former are reduced by a factor ϵ. This reduction may be accounted for by two basic facts:

- Flange bending stress produces a local stress peak only. The flange bending stress is very rapidly attenuated in the longitudinal direction of the girder. At a distance of 10 mm from the point of the maximum, the flange bending stress is approximately only a half of the maximum.
- Taking into account local flange bending stresses increases the accuracy of the calculation. This prevents uncertainties, which would allow a lower safety factor ν.

$$\nu = \frac{\sigma_{yield\ point}}{\sigma_{perm}}$$

The value ϵ was arrived at by comparing the results of calculations for numerous single-girder overhead travelling cranes on the basis of both the traditional and the FEM methods. Consideration was given to cranes which had not been damaged by flange bending stresses even after many years of operation.

The flange bending stresses which accur are proved using a calculation example and the superimposition of flange bending stresses on main stresses demonstrated.

*) This inequality represents an unfavourable condition, allowing values slightly above 1. If this is so, the following inequality is used for the calculation:

$$\sqrt{\left(\frac{\sigma_{x\,max}}{\sigma_{xa}}\right)^2 + \left(\frac{\sigma_{z\,max}}{\sigma_{za}}\right)^2 - \frac{\sigma_{x\,max} \cdot \sigma_{z\,max}}{|\sigma_{xa}| \cdot |\sigma_{za}|} + \left(\frac{\tau_{xz\,max}}{\tau_{xza}}\right)^2} \leqslant 1{,}05$$