DESIGN OF Z-PURLINS: PART 1

Basics and cross section values according to EN 1993-1-3

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INTRODUCTION

Z-purlins are possibly the most commonly used cold formed beams. They are mainly used for roof and wall purlins instead or hot rolled I-sections or U-channels.
Unlike hot rolled sections, Z-purlins are thin-walled and non-symmetrical sections. For instance flanges can show width-to-thickness ratios (c/t) approx. 30 to 40, whereas flanges of hot rolled sections are usually below 10. Therefore some effects like flange curling, local buckling and distortional buckling which are of secondary importance for hot rolled sections have to be taken into account.
According to the rules of EC 3-1-3 these effects have to be considered by determination of net cross section parameters.
Flange curling is a local deformation of a flange under tension or compression due to bending in combination with the deflection of the purlin. This effect has to be considered by reducing the height of the cross section.
Whereas flange curling is a common deformation due to internal stresses, local buckling and distortional buckling are caused by local instability. Buckling of cross section elements without stiffeners are considered by an effective width (class 4 cross section).
Distortional buckling, that means local buckling of flanges with edge and/or intermediate stiffeners is taken into account by an effective sheet thickness.
The net cross section parameters have to be determined iteratively, despite of the fact that some rules of EC 3-1-3 have been simplified compared to the former German standard DASt-Richtlinie 016.

1 GENERAL

Z-purlins are thin-gauge lightweight construction elements which are mainly used as roof purlins and sheeting rails. They are easy and economical to manufacture from flat steel of 1,5mm to 4mm thickness by roll forming or bending. Usually strip galvanized flat steel is used.
Classical hot rolled purlins can also be designed economically by plastic analysis considering the stabilizing effects of roof cladding. Despite of this fact the use of Z-purlins achieves savings of material up to 20% for common spans and common loading.

Tab. 1. Advantages of hot rolled purlins and Z-purlins

Hot rolled purlins	Z-Purlins
Advantages ▪ symmetrical cross section ▪ standard analysis ▪ simple construction details ▪ global plastic analysis is usually possible Disadvantages ▪ increased material usage	Advantages ▪ better adaptation of cross section to the bending moment curve ▪ saving of material up to 20% ▪ usually cheaper purchase price of material Disadvantages ▪ non-symmetrical cross section ▪ complex analysis ▪ more complex construction details ▪ low normal force bearing capacity

Figure 1 shows typical cross sections of Z-purlins which are currently available on the market. The lower flange is always smaller than the upper flange to fit the purlins into each other. This is a demand for the construction of continuous beams which can be carried out as overlap or sleeve systems. Because of economical reasons the use of single span beams is rare.

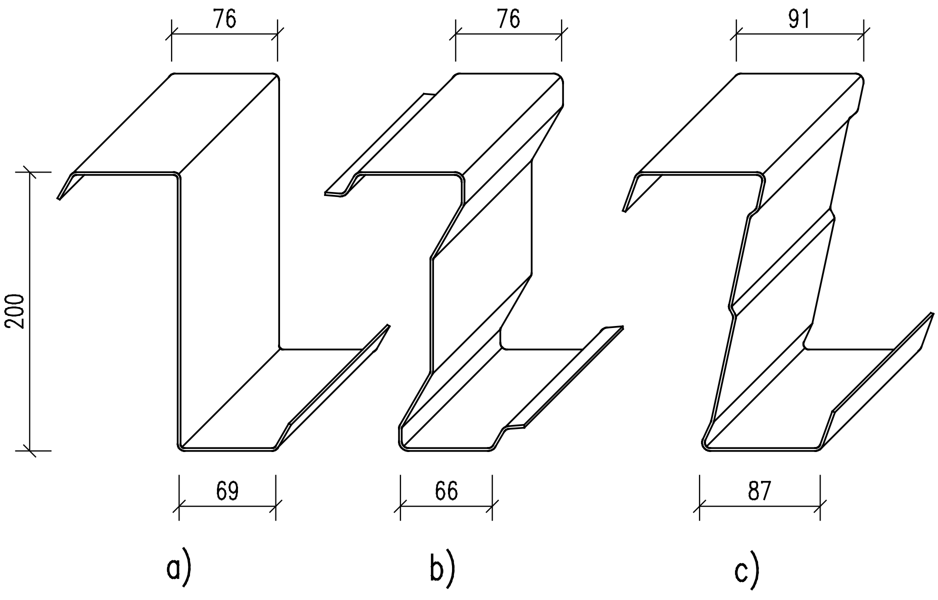

Fig. 1. Typical cross sections of Z-purlins

The overlap system is the most competitive way to use Z-purlins. It allows an optimum adaptations of cross section to the bending moments.
The overlapping cross sections above the supports are able to carry the higher hogging moments. In general thicker sheets are used for the end spans because of the higher sagging moments in this area. A typical overlap length *e* is 10% of the span. Only the outer overlap of the second span should be longer because the end spans exert an influence on the range of the adjacent hogging moments.

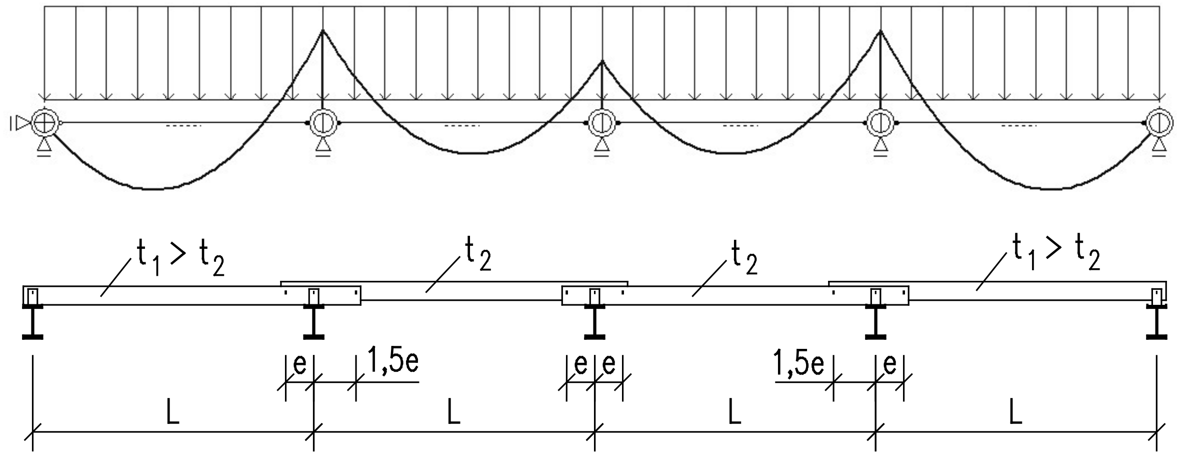

Fig. 2. Overlap system

2 MATERIAL PROPERTIES OF COLD FORMED SECTIONS

All steels used for Z-purlins shall be suitable for cold-forming. Material commonly used is S320GD according to EN 10147.
The effect of cold working can to be taken into account. Eurocode 3-1-3 [1] provides rules for the determination of an increased yield strength depending on the number of bents and the method of profiling. This increased yield strength can be used for cross section areas under tension in general and for areas under compression if no local buckling occurs.

3 GROSS CROSS SECTION PARAMETERS

Z-purlins are usually calculated in consideration of the stabilizing effects of roof sheeting. A sufficient horizontal support of the top flange is a condition for the use of lightweight purlins. For the stabilization of the free lower flange a sufficient rotational restraint is necessary.

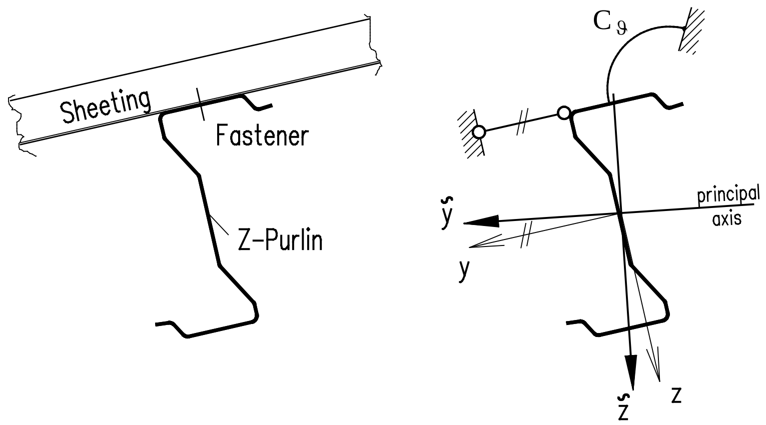

Fig. 3. Diaphragm braced Z-purlin and idealized system

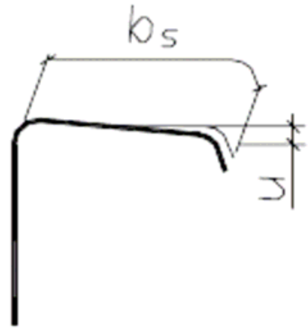

Fig. 4. Flange curling

Usually the calculation of a beam is carried out about the major axis because in this case the differential equations for the bending about major and minor axis are independent from each other. Z-purlins are an exception because the idealized system has a bound axis supported by rotational

spring per unit length (see [3], [4], [5]). Therefore the check is done about the axis parallel to the roof sheeting.
The following gross cross section parameters are needed for calculation:

- Moments of inertia I_y and I_z
- Product of inertia I_{yz}
- Warping constant I_w
- Torsion constant I_t

Torsion is considered as bending of free flange about z-axis. Therefore the elastic section modulus of the free flange W_{fz} and the radius of gyration of the free flange i_{fz} have to be determined as well.
A special phenomenon of thin-gauge lightweight sections is the so called flange curling, that means an inward curvature of flange towards the neutral plane. It is caused by compression an tension stresses.
If the curling of flange is larger than 5% of the cross section height it has to be taken into account by a reduction of the arithmetical cross section height.

The fabrication by roll forming or bending leads to a cross section with rounded corners. The cross section parameters should be determined based upon the actual geometry. In practice the cross section parameters are determined first for cross sections with sharp corners. Thereafter they are reduced by means of approximation formulas given in the Eurocode [1].

4 NET CROSS SECTION PARAMETERS

Because of the thin walled cross sections the postcritical load bearing capacity has to be taken into account. The phenomenon of local plate buckling is known from slim hot rolled sections as well. Using Z-purlins it is superimposed by a second phenomenon. This is distortional buckling which can be explained as buckling of the edge stiffener of the compression flange. The buckling resistance of a stiffener depends on the slenderness of the stiffener itself and from the continuous partial restraint by a spring stiffness depending on the adjacent parts of cross section.
Local plate buckling is considered by calculation of the effective width (class 4 cross section). Distortional buckling is considered with a second step by the reduction of thickness of the edge stiffener.
Optionally the reduced cross section area can be improved iteratively by using a reduced compression force. Figure 5 shows a flow-chart for the determination of the effective area of compression flange. This procedure is simplified compared to the ENV1993-1-3 or the DASt-standard [2] where two nested loops are necessary.

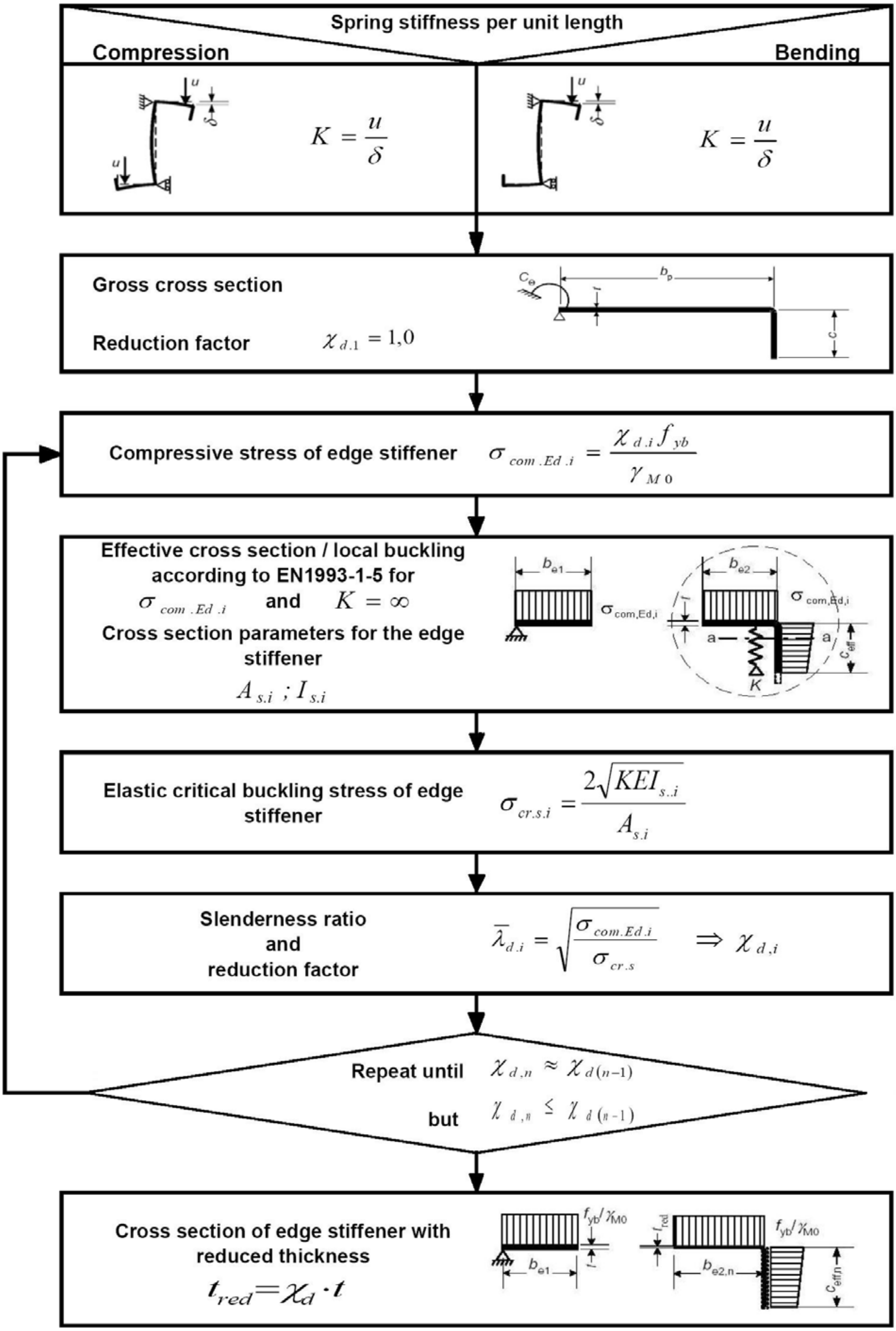

Fig. 5. Iteration procedure for the determination of net cross section of flanges

Figure 6 shows an example of a typical iteration process. The effective area of stiffener was found after 14 iterations.

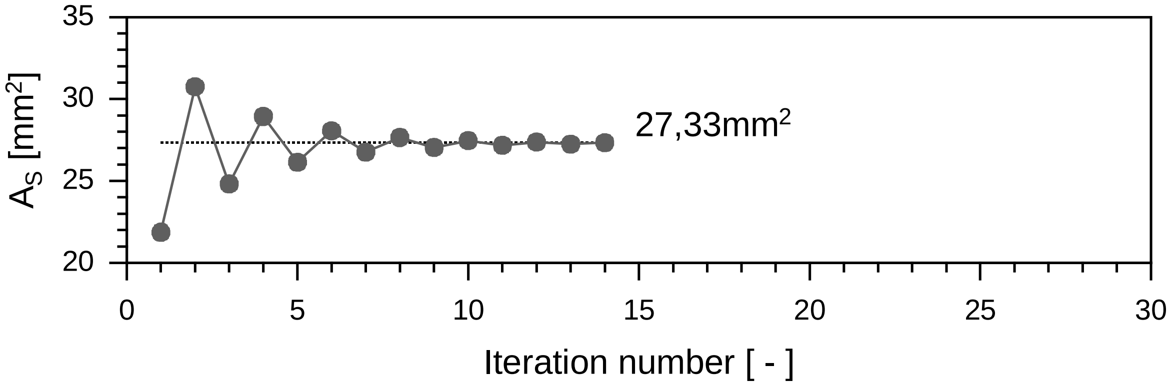

Fig. 6. Iteration example

The effective width of web areas under compression is calculated as usual for class 4 cross sections. The following net cross section parameters have to be used for calculation:

- Net section modulus about major axis $W_{eff.y}$ (positive/negative position)
- Net cross section area A_{eff}

REFERENCES

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