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Checking and supplementing of the imperfection assumptions and erection rules of DIN EN 1995-1-1 for constructions with punched metal plate fasteners in order to increase the safety and cost-effectiveness of the latter

Summary

Research project

commissioned by

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P 52-5- 13.188-1430/13

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in September 2014

In February 2011, the commission of experts responsible for structural engineering within the Bauministerkonferenz (ARGEBAU) published both guidelines for the planning and design of constructions with punched metal plate fasteners and notes on the checking of statical calculation and the monitoring of construction work.

The guidelines contain no details on the imperfections relevant for the load-bearing capacity of a construction and their absolute dimensions, no details on processes to minimise imperfections during erection and likewise no details on the limit sizes of imperfections required for inspection work (permissible bow and sway imperfections).

It was therefore deemed necessary to take a representative sample of constructions (consisting of 10 constructions each with 20 similar individual members) in order to measure any possible imperfections directly after erection and to evaluate these with regard to size, shape and probability of occurrence.

All 10 constructions were proposed by truss fabricators. The constructions were selected by the authors with the aim of measuring as many truss forms with differing spans and roof pitches as possible. The trusses were erected by 9 assembly companies. The results of the 4 constructions which were already measured in 2009 were included in the evaluation of this project. Taking into account organisational feasibility, this sample of 14 constructions offers the highest level of representativeness possible.

As in 2009, the 9-10 trusses of the 10 representative, newly erected constructions were measured with an electronic theodolite. The three-dimensional coordinates were transferred directly to the three-dimensional CAD system cadwork®and stored there as 3D models. The sample includes 238 sway imperfections and 246 upper chord bow imperfections.

With the aid of a stochastic model for random and systematic imperfections, it was possible to describe the influence of the number n of the trusses of a collective on the effects of the imperfections of the n trusses on their bracing system by a factor $k_{sim.}$ This factor is the ratio of the standard deviation of the mean imperfection of a collective of n neighbouring trusses to the standard deviation of the imperfection of an individual truss.

The alignment of imperfection forms and buckling modes of the three-dimensional stabilising structure and its parts and the ratio of structural to geometrical imperfections as a function of the respective buckling mode play an important role in the establishing of control and design values.

As a result, it is recommended for the sway imperfections of a collective of neighbouring trusses with punched metal plate fasteners which are stressed more or less to the same degree, that the following limit values be adhered to in the kink points:

a) The arithmetical mean of the sway imperfections of the trusses standing between two bracing systems may not exceed $a_{dev,\,mean,perm} = h/300$ in a kink point so that $1/300 < k_{sim} \cdot 1/200$ is valid.
b) If the trusses of a collective are oriented to a bracing system, the unplanned sway imperfection of this bracing system may not exceed $a_{dev,dia,perm} = h/400$. The very time-consuming checking of the arithmetical mean of the collective is then no longer necessary.
c) The sway imperfection of an individual truss of a collective may not exceed $a_{dev,single,perm} = \min(h/100; 50\ mm)$.

For the design of the stabilising members, the design value of the sway imperfection then amounts to

$$\phi_n = \frac{1}{200} k_{sim,\phi} \quad \text{mit} \quad k_{sim,\phi} = \sqrt{\frac{1}{2}\left(1 + \frac{1}{n}\right)}$$

The alignment of imperfection forms and buckling modes of the three-dimensional stabilising structure and its parts and the ratio of structural to geometrical imperfections as a function of the respective buckling mode play an important role in the establishing of control and design values for bow imperfection.

In a construction of neighbouring trusses with punched metal plate fasteners which are stressed to more or less the same degree, the bow imperfections of the compressed chord sections between two bracing systems must comply with the following limit value:

a) The arithmetical mean of the related maximum deviations (bow imperfections) of trusses standing between two bracing systems may not exceed $a_{bow,\ mean,\ perm} = \ell/500$ where ℓ is the distance between kink points.

Differing bow imperfection values are recommended with which to calculate the bending stress of a compression chord between two kink points of a truss with punched metal plate fasteners and for the design of the members stabilising the compression chord. Recommendations are also made for erection work and the checking of the same.