GRISPE PLUS

VALORISATION OF KNOWLEDGE FOR SPECIFIC PROFILED STEEL SHEETS

HOLED PROFILES

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Sources

The project has received financial support from the European Community (RFCS programme) under grant agreement No 754092

Holed profiles

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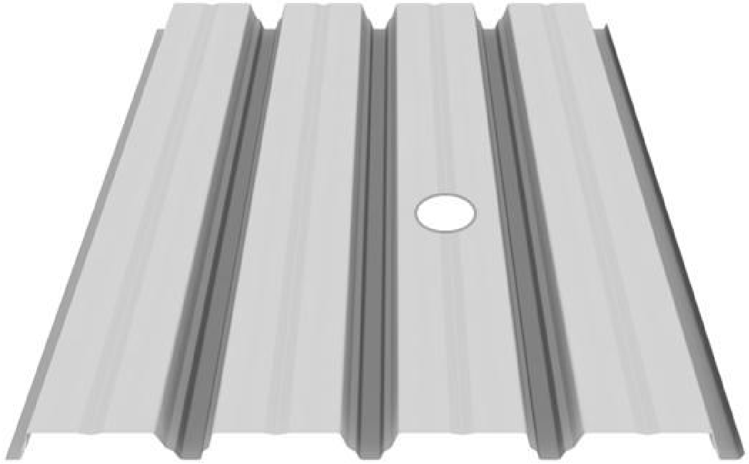
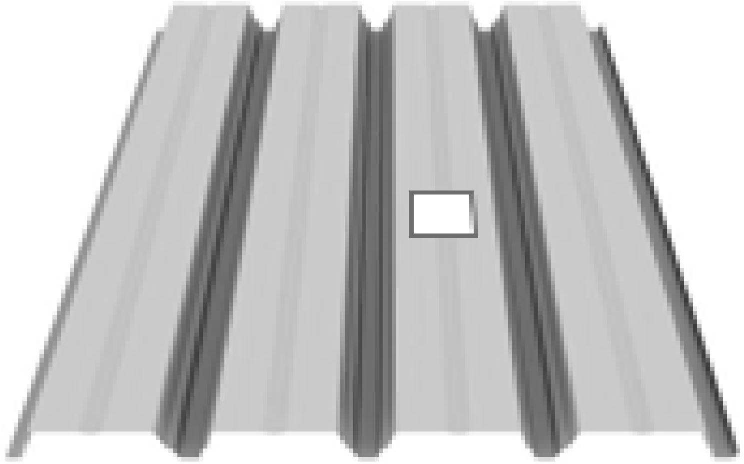
1. INTRODUCTION

Holes are often required in the flange of steel profiles for the passage of services. The holes may be circular or square and of different sizes. Most often there is only one hole on one rib of the profile.





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1. INTRODUCTION

The current version EN 1993-1-3 provides the design rules for cold-formed sheeting including profiled sheets profiles without a hole.

The EN 1993-1-3 stipulates that:

1) The effects of local and distortional buckling should be taken into account in determining the resistance and stiffness of cold-formed members and sheeting.
2) Local buckling effects may be accounted for by using effective cross-sectional properties, calculated on the basis of the effective widths, see EN 1993-1-5.
3) In determining resistance to local buckling, the yield strength f_y should be taken as f_{yb} when calculating effective widths of compressed elements in EN 1993-1-5.

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Holed profiles

1. INTRODUCTION

The previous studies on profiles with a hole [1] to [6] found in the literature only deal with buckling and postbuckling of plates subjected to compression and shear loadings, and do not give any data about moment resistance calculation.

Nevertheless these studies show that holes reduce the profile strenght locally and globally.

[1] M. AZHARI, A. R. SHAHIDI, M. M. SAADATPOUR "LOCAL AND POST LOCAL BUCKLING OF STEPPED AND PERFORATED THIN PLATES" 2005
[2] C.J. BROWN, A.L. YETTRAM, M. BURNETT, STABILITY OF PLATES WITH RECTANGULAR HOLES, J. STRUCT. ENG. 1131111–1116, 1987
[3] F-Y. CHOW, R. NARAYANAN "BUCKLING OF PLATES CONTAINING OPENINGS" 1984
[4] R. NARAYANAN, F-Y. CHOW "STRENGTH OF BIAXIALLY COMPRESSED PERFORATED PLATES" 1984
[5] PAIK J.K. "ULTIMATE STRENGTH OF PERFORATED STEEL PLATES UNDER EDGE SHEAR LOADING", THIN-WALLED STRUCTURES 45, 2007
[6] SHANMUGAM N.E "DESIGN FORMULA FOR AXIALLY COMPRESSED ERFORATED PLATES" THIN-WALLED STRUCTURES 34, 1999

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2. STATE OF THE ART PRE-GRISPE

Issue identified by the GRISPE project:

- In practice square or circular holes in the flange of sheeting are often required for the passage of services.
- However, the current version of EN 1993-1-3 does not provide information on how to deal with this kind of hole in calculation of the moment resistance of the section.
- The only way to design these products is to carry out tests according to EN 1993-1-3 (expensive and time consuming)

There is a real lack of data and knowledge on how to determine resistance and stiffness of steel profiles with a

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2. STATE OF THE ART PRE-GRISPE

GRISPE objectives and methodology:

The main objectives were to provide technical data and a calculation method for profiles with a circular or a square hole.

The missing data were determined by testing.

Based on the tests analysis a calculation method was developed and validated

An Amendment was proposed to CEN TC 250/SC3/WG3 EN 1993-1-3

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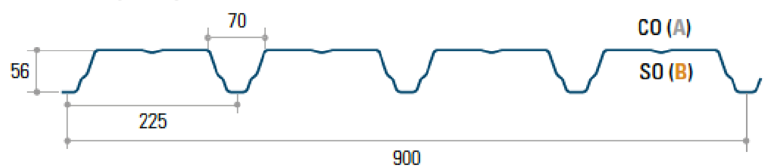
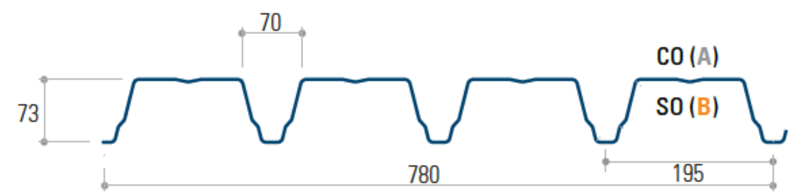
3. TESTING

Aim of the testing:

- to determine the resistance values of two types of profile without a hole and with a square or a circular hole





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- to compare these values for profiles without a hole and with a square or a circular hole
- to determine the impact of a hole on the structural behaviour: resistance and stiffness.
- to define a calculation rule for profiles with a hole

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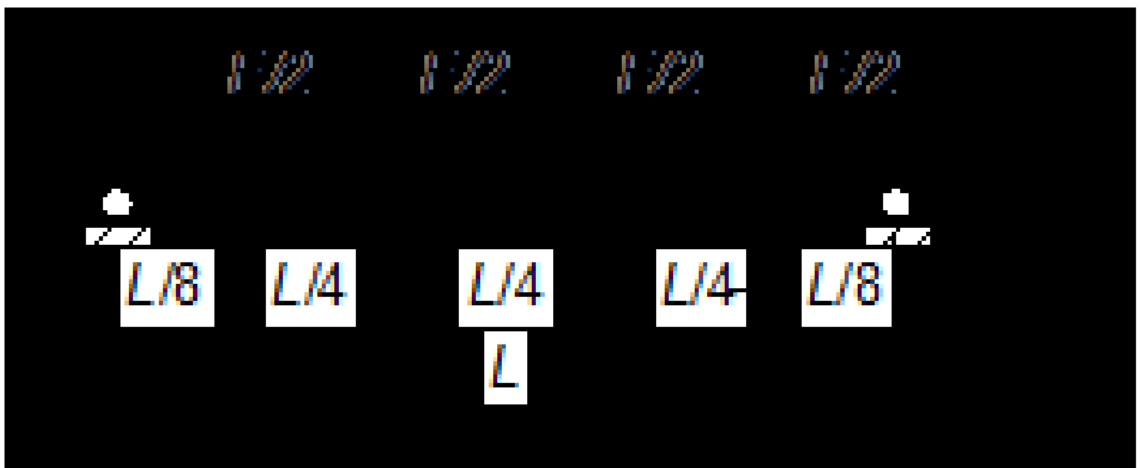
3. TESTING

<u>Global testing performed within the GRISPE project</u>:

- Single span tests according to EN 1993-1-3, Annex A, on two types of profile, without a hole and with a square or a circular hole



Single span test configuration according to EN 1993-1-3

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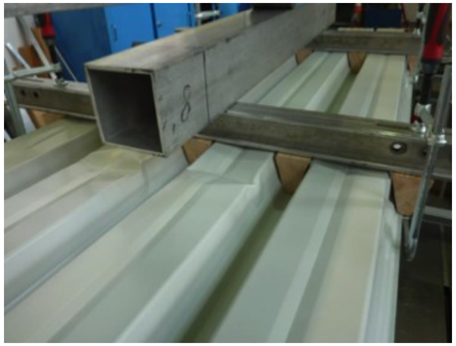
Holed profiles

3. TESTING

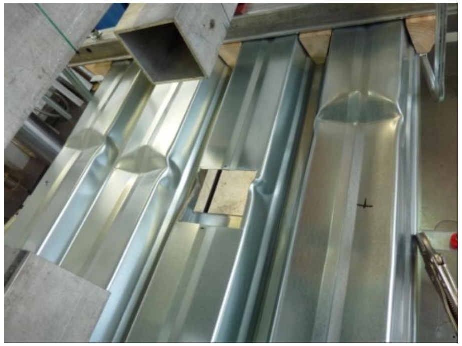
<u>Single span test results</u>:

- Determination of the <u>moment resistance</u> and of the effective flexion <u>stiffness</u> (inertia moment)
- <u>Failure mode</u>: buckling of the upper (without and with a circular or a square hole)



Without a hole

With a circular hole



With a square hole

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3. TESTING

Global behaviour test results:

Determination of the effect of a circular or a square hole in the upper flange, on the structural behaviour (resistance and stiffness of the steel profile) ➔ Circular and square holes induce similar decrease of the resistance

↘	Moment Resistance	Inertia Moment Resistance
Hole d=90mm	4% - 7%	0% - 4%
Hole d=105mm	6% - 11%	0% - 6%
Hole d=120mm	13% - 15%	2% - 9%

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4. DESIGN AND CALCULATION

Moment resistance and stiffness determined by calculation:

For profiles without a hole the moment resistance of the profile is calculated according to EN 1993-1-3 where the effective width of the flange area is calculated according to EN 1993-1-5 with the gross cross-sectional area Ac: Ac,eff = ρ Ac where ρ is the reduction factor for plate buckling.

The flanges are considered as internal compression elements, the reduction factor ρ is :

$$\rho = \frac{\bar{\lambda}_p - 0{,}055\,(3 + \psi)}{\bar{\lambda}_p^2} \leq 1{,}0$$

and effective width b is determined according to Table 4.1: Internal compression elements of EN 1993-1-5

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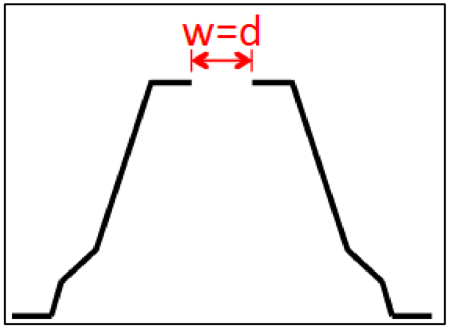
4. DESIGN AND CALCULATION

Moment resistance and stiffness determined by calculation:

For profiles with a circular or a square hole:



As when the diameter of the circular hole (d) is equal to the width of the square hole (w) the influence of the hole on resistant moment is quite similar, the same model of calculation is proposed for square and circular holes depending on the width of the hole in the flange section.

The moment resistance of the profile is the sum of the moment resistance of ribs without a hole and of the moment resistance of the rib with a hole.

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4. DESIGN AND CALCULATION

The effective flange area is calculated according to EN 1993-1-5 with the gross cross-sectional area Ac: Ac,eff = ρ Ac where ρ is the reduction factor for plate buckling.

- The flanges without a hole are considered as internal compression elements, the reduction factor ρ is:

$$\rho = \frac{\bar{\lambda}_p - 0{,}055\,(3+\psi)}{\bar{\lambda}_p^{\,2}} \leq 1{,}0$$

and effective width b is determined according to Table 4.1: Internal compression elements of EN 1993-1-5

- Both parts of the flange with a hole are considered as outstand compression elements, the reduction factor ρ is:

$$\rho = \frac{\bar{\lambda}_p - 0{,}188}{\bar{\lambda}_p^{\,2}} \leq 1{,}0$$

and effective width b is determined according to Table 4.2: Outstand compression elements of EN 1993-1-5

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4. DESIGN AND CALCULATION

Results:

The moment resistance determined by calculation is compared to the moment resistance determined by testing

The comparison confirms that:

- The definition of the moment resistance as the sum of the moment resistance of ribs without a hole and of the moment resistance of the rib with a hole.
- Where the effective flange with a hole area is calculated considering both parts of the flange with a hole as outstand compression elements

gives results that are coherent and safe in relation with the testing results.

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5. AMENDMENT TO EN 1993-1-3

Add a new Section 10.5:

10.5 Sheeting with a hole in the flange

In case of a circular or square hole in the compressed upper flange, the effective width of the flange parts adjacent to the webs may be determined considering them as as outstand elements of width b_p (see figure 10.16).

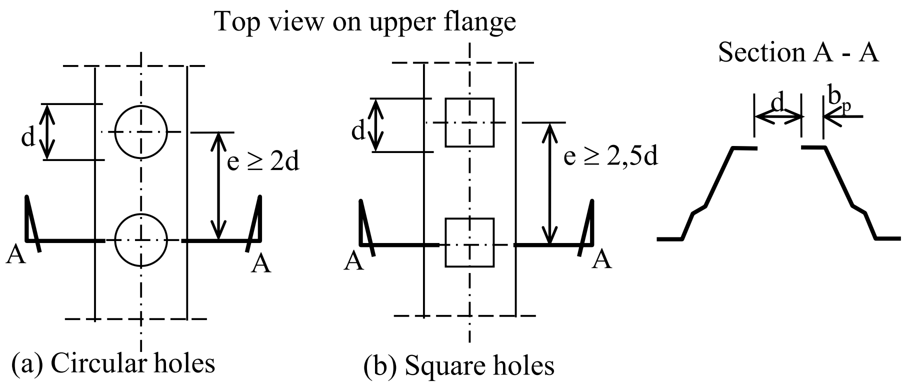

Fig. 10.16: Sheeting with circular (a) or square (b) holes in flange

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6. EXCEL SHEETS

An excel file was developed to provide a reliable design procedure in order to encourage and facilitate the use of steel decks with outwards stiffeners:

The overall aim was to achieve simple, clear, easy to understand and easy to use excel sheets. The excel file was validated by the comparison of the calculation results with all the tests which have been carried out. Moreover the calculation methods have been made available to a number of industry users to verify their fitness for purpose.

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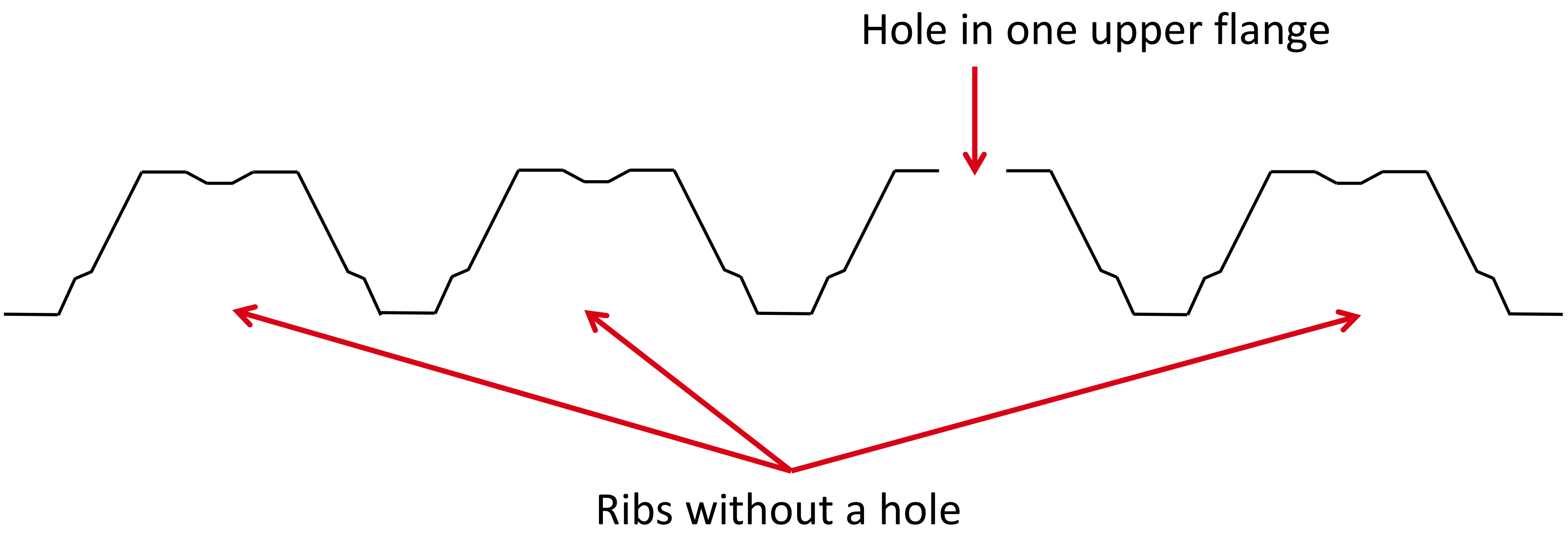
6. EXCEL SHEETS

- Calculation of span moment resistance for a profile with a circular or a square hole in the upper flange.



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7. CONCLUSION

- The design by calculation method of profiles with a circular or a square hole presented here, was checked and validated by an extensive test programme performed within the GRISPE project.
- An Excel sheet including this method was developed for calculation of moment resistance for a profile with a circular or a square hole in the upper flange
- This design by calculation method was proposed for amendment on EN 1993-1-3 within CEN/TC250 Subcommittee 3 (SC3) “Steel Structures”.

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Thank you for your attention

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