GRISPE PLUS

VALORISATION OF KNOWLEDGE FOR SPECIFIC PROFILED STEEL SHEETS

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PARIS WORKSHOP documentation

Valorisation of knowledge for specific profiled steel sheets: how to design by calculation seven families of steel profiles?

5th October 2017

Paris, France

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

GRISPE PLUS
VALORISATION OF KNOWLEDGE FOR SPECIFIC PROFILED STEEL SHEETS

INVITATION WORKSHOP

5 Octobre 2017	23 Janvier 2018	15 Mars 2018	14 Juin 2018	Novembre 2018
Paris, France	Aachen, Allemagne	Pise, Italie	Cracovie, Pologne	Helsinki, Finlande

PROGRAMME

(Les présentations sont données en anglais)

INTRODUCTION

9.00-9.10 LES PROJETS GRISPE ET GRISPE PLUS
Valerie PRUDOR - L'Enveloppe Métallique du Bâtiment

9.10-9.20 E-TEACHING GRISPE PLUS: DIFFUSION DES RÉSULTATS DE GRISPE GRÂCE AUX E-LECTURES
Roman BREUER - RWTH AACHEN

COMMENT DIMENSIONNER PAR CALCUL LES 7 FAMILLES DE PROFILS ?

9.20-10.05 BACS ACIER DE PLANCHERS COLLABORANTS AVEC BOSSAGES/INDENTATIONS ET/OU RAIDISSEURS POINTANT VERS L'EXTÉRIEUR
Anna PALISSON – SPC Consultants

10.05-10.50 PROFILS ONDULÉS
Thibaut RENAUX – JORIS IDE

10.50- 11.35 PLATEAUX
Markus KUHNHENNE – RWTH AACHEN

11.35 Pause Café

11. 50 -12.35 ASSEMBLAGES DE CONTINUITÉ DE PROFILS
Thibaut RENAUX – JORIS IDE

12.35 -13.45 Déjeuner

13.45- 14.30 PROFILS CINTRÉS
Sylvia- CAPRILI - UNIVERSITY OF PISA

14.30-15.15 PROFILS PERFORÉS ET PROFILS AVEC OUVERTURES
Anna PALISSON – SPC Consultants

15.15- 16.00 LAMES DE PAREMENT À FIXATIONS CACHÉES ET LEUR EMBOÎTEMENT
Mickael BLANC – BACACIER

CONCLUSION

16.00-16.45-PROPOSITION D'AMENDEMENTS À L'EUROCODE 3 PARTIE 1-3
David IZABEL – L'Enveloppe Métallique du Bâtiment

16.45 Fin

A QUI S'ADRESSE LE WORKSHOP ?
Ce workshop s'adresse aux producteurs d'acier, aux fabricants de profils en acier, aux entreprises qui les mettent en oeuvre, aux étudiants en génie civil et en construction métallique, aux experts en codification, aux chercheurs et aux membres des comités Eurocode et en particulier au TC 250

DOCUMENTATION REMISE
Un rapport complet, en anglais et en français, contenant les points forts des discussions sera remis aux participants. Les présentations seront également disponibles pour les participants.

LA PARTICIPATION EST GRATUITE MAIS L'INSCRIPTION EST OBLIGATOIRE.
Le nombre de places étant limité, elles seront attribuées dans l'ordre des dates d'inscription.

WWW.GRISPEPLUS.EU

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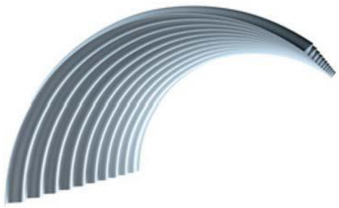
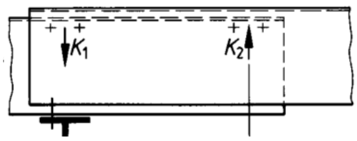
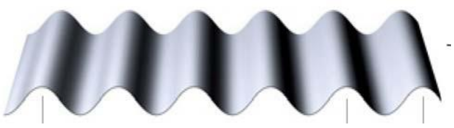
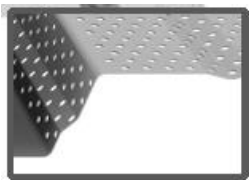
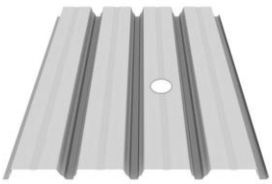
Università di Pisa · JORISIDE · L'Enveloppe Métallique du Bâtiment · BACACIER · RWTH AACHEN UNIVERSITY · SPC · Cracow University of Technology

1. Introduction

Valerie Prudor, Secretary General of the Enveloppe Metallique du Batiment and Project Coordinator, outlined the aims and objectives of the GRISPE and GRISPE PLUS projects and the purpose of the workshop.

The objective of GRISPE PLUS is the promotion, dissemination, valorization and use in practice of the knowledge obtained on seven families of steel profiles in the European funded project GRISPE (2013-2016).

The GRISPE project was aimed at providing technical data and calculation methods for specific steel profiles (steel decks, liner trays, corrugated sheeting, curved and assembled profiles, perforated and holed profiles and interlocking planks) which are not or incompletely included in the current version of Eurocode EN 1993-1-3 despite their growing importance for the European steel and construction sectors.

STEEL DECKS WITH EMBOSSMENTS OR STIFFNERS 	CURVED PROFILES 
LINER TRAYS 	ASSEMBLED PROFILES 
CORRUGATED SHEETINGS 	PERFORATED OR HOLED PROFILES  
CLADDING SYSTEMS 	

In order to provide technical data and calculation methods for these seven families of steel profiles, five main tasks were performed including the preparation of a comprehensive critical review of the state of the art, the performance of an extensive experimental programme aimed at filling in the existing gaps in knowledge, the development of innovative design and calculation and of easy to use design Excel software sheets and the completion of a series of standardisation briefs to facilitate their inclusion into EN1993-1-3.

The GRISPE PLUS project proposes a series of tools to easily access and understand the knowledge generated with an on-line central resource (www.grispeplus.eu)- a series of design manuals et worked examples in five languages (English, German, Polish, Italian and French), a series of workshops (of which this is the first) organised in strategically placed locations across the European Union and importantly ten E-lectures.
In response to a question, it was stressed that although the working language of the project was English, most of the key documents will be provided in a range of other European languages.

Roman Breuer from RWTH Aachen introduced the E-teaching strategy of GRISPE PLUS and how E-lectures are used to disseminate the GRISPE results
Learning was happening increasingly online using a range of different electronic devices and digital media and at a time and place of the student's choosing.
eLearning was underpinned by a number of theories including in particular dual coding and cognitive load theories and made use of models such as the selection-organisation-integration (SOI) model.
eLearning in the project imparted knowledge while allowing for self-assessment and reinforcement through information for further reading.
Visuals of a typical electure were presented and discussed. A programme of 10 electures will be made freely available to the public.

Anna Palisson from SPC Consultants presented the results of the work which had been carried out on ***Steel decks with embossments/Indentations and/or outwards stiffeners***.
In order to increase the shear connection between the steel and the concrete in the composite slabs, steel decks are reinforced with connectors such as embossments or indentations on the webs.
The sheeting used as shuttering has to support the fresh concrete weight and the construction loads.
EN 1994-1-1 specifies that steel sheeting should be designed in accordance with EN 1993-1-3. However, the current version EN 1993-1-3 does not provide any information on how to deal with the indentations or embossments in calculation

of the effective section. The GRISPE project addressed this issue by developing a calculation method of steel decks with embossments / indentations.
An extensive experimental programme showed that the difference between the calculated moment resistance and the tested one was coherent with the difference observed for the profiles without embossments / indentations and that
the embossments / indentations could be considered as plate elements with a reduced thickness $t_{red} = \rho * t$ where $\rho = A*h + B$, h is height of the embossments / indentations , A and B are coefficients defined as before, gives coherent and safe results in relation with the testing results. It also showed that a safe simplification could be made where the web crippling resistance may be determined without considering embossments / indentations.
The two amendments which have been proposed to CEN concern the effective section of sheeting with embossments/indentations and the resistance of sheeting with indentations or embossments to combined bending moment and local or support reaction.
In current practice, in order to increase the horizontal shear resistance between the steel sheeting and concrete, outwards intermediate stiffeners in dovetail form are often placed in the upper flange. The current version EN 1993-1-3 does not provide information on how to deal with this kind of stiffener in calculation of the moment resistance of the section. A design by calculation method of steel decks with outwards stiffeners was developed within the GRISPE project. It is based on the results and analysis of an extensive experimental programme.

The amendment which has been proposed to CEN add a new clause in the section 5.5.3.3 of EN 1993-1-3 to read:
(12) For intermediate stiffeners facing outwards of sheeting flanges used for composite slabs, the calculations should be performed by taking the stress in the stiffener as equal to the stress in the flange.

Five Excel sheets are available to calculate the moment resistance, end support reaction and moment-reaction interaction at internal support of steel decks with embossments / indentations and of steel decks with outwards stiffeners

Thibaut Renaux from Joris Ide presented the results of GRISPE for ***Corrugated sheetings***.
Corrugated steel sheet are common solutions for metallic roofing and cladding but existing Eurocode EN 1993-1-3 does not provide a design calculation method.
Following a substantial test programme two design approaches for the corrugated sheets in bending were studied in the course of the GRISPE project.
A combination of two methods was finally proposed: a detailed method based on the approach adopted in the Swedish code StBK-N5 for light gauge metal

structures and a simplified method with a field of application calibrated on the tests done during GRISPE project.
For the behaviour of corrugated sheets on intermediate support the results of GRISPE do not show a clear rule as too many parameters have to be taken into account. More tests will be necessary in order to reach a viable conclusion. The reduction of the ultimate bending moment is influenced by the R/t ratio, the pitch of the cross section, the width of the support and the size of the support reaction/load, location and direction of the load (sensitivity of section against local loads).

Dominic Pyschny from RWTH Aachen presented the work which had been done on ***liner trays***
Liner trays are trough-like cold formed steel component with wide flange with two webs and two smaller flanges which are stiffened with outward profiles. They are mostly used for inner sheets of walls, but can also be used for roof lower sheets. The flanges and webs are reinforced with stiffeners like folds, bends and grooves. One of the issues arising from their use in wall systems concerns their thermal performance and the various solutions which have been developed to reduce the thermal bridge effects.
EN 1993-1-3 proposes a step by step procedure to determine the moment resistance of a liner tray restrained by sheeting with its wide flange in tension. The actual Eurocode design rule taking into account the effect of the fixing distance s1 is rather conservative, and furthermore limited to a maximum fixing distance s1 = 1000 mm.

The work of GRISPE results from the fact that conventional liner tray wall systems with thermal separation strip do not fulfil the actual energy requirements and that new solutions are developed for which no calculation methods are available in current regulations, or application boundaries of existing methods are exceeded. The aim of was to develop a new calculation for β b as a function of fixing distance s1.
Extensive experimental investigations have been performed on liner trays with directly fixed outer façade for fastener distances that are normatively not or insufficiently covered.
Practicable calculation methods have been derived based on existing regulations and methods and have been compared to test results.

Thibaut Renaux from Joris Ide presented the work which had been carried out for ***Assembled profiles***.
The component under consideration here are trapezoidal steel decks assembled for flat roofing for which the Eurocodes do not currently provide any calculation or design solutions.
A large number of tests, simulating the behaviour on intermediate support, were carried out on three types of joints including joints according to DIN 18807-3 (DIN-joint), overlapping joints (OL) and continuous profiles with local

reinforcements joints (CR) completed by tests on continuous profiles in order to carry out a comparison.
The results of the work were that the DIN-joint provides the same load bearing capacity as continuous profile with an overlap sufficiently long, that the overlap length should be designed in a way that excludes web crippling at the end of the overlap and that a sufficient overlap length should be checked by an additional verification of the shear force at the end of the overlap.
For assemblies with double cross section (OL and CR) the work showed that they provides 180 % of the resistance of a simple continuous profile, that the overlap length should be designed in a way that exclude web crippling at the end of the overlap is excluded and that a sufficient overlap length should be checked by an additional verification of the shear force at the end of the overlap

Sylvia Caprili from University of Pisa spoke on ***curved profiles***.
Curved profiles can be obtained through three different processes: roll forming, crushing of the inner flange or in situ bending. The GRISPE project concentrated on investigating the changes in the structural performance of curved profiles obtained through a continuous roll forming process when compared to flat profiles. Data presented in the current scientific literature refer to variation of the bearing capacity of curved profiles respect to flat profiles of around 10% to 30%.
A wide test program was performed to determine the load-bearing capacity of curved profiles in bending for different bending radii. Two different configurations were selected for the execution of experimental tests, respectively for the analysis of the structural performance of the curved profile under only bending actions and, on the other hand, under the combined condition of bending and axial forces.

The design model and guidelines which are proposed for curved profiles reduce the bending moment capacity by 10 % compared to the bending moment capacity of the flat profile.
For curved profiles with horizontal support (arch) it is proposed to use the following design procedure:
1. The internal forces of the arch (bending moments, axial forces) should be calculated using the gross cross section values Ag and Jg of the profiled sheeting.
2. The horizontal displacement at supports must not be neglected as the greater the displacement is estimated the more unfavourable the internal forces become. Therefore it is necessary to take into account the horizontal displacement by modelling the support with a horizontal spring. The spring stiffness, which depends on the substructure and the fixing of the profiled sheeting, should be adjusted, so that the calculated horizontal displacements meet the real values. To avoid unsafe design, the spring stiffness should not be over-estimated. Under-estimation of the spring stiffness leads to an over-

estimation of the horizontal displacements and in consequence to a design on the safe side.
3. The bending moment – axial compression – interaction should be calculated with the interaction formula of DIN 18807, but without limitation of α to 1.
4. The design model is verified for arches with symmetric loading. If it is also applicable for arches with not symmetric loading, should be researched in another project.

Anna Palisson from SPC Consultants presented the work on ***Perforated and holed profiles***.
For architectural reasons and for a better acoustic performance perforated profiles are increasingly developed and used. Different types, geometries and distribution of micro-perforations (in triangle, in square) exist on the profile web and on the flange. In practice sheeting with square distribution of perforations is often used, but the information is missing as to the design rules for this case.
The current version EN 1993-1-3 provides the design rules sheeting with triangular equilateral distribution of perforation.
A design by calculation method of profiles with perforations arranged in square was developed within the GRISPE project.
For perforations in the web or in the flange the difference observed between the calculated moment resistance and the tested one is coherent with the difference observed for the profiles without perforations. Replacing t_{eff} by 0,93 * t_{eff} and a by a = 1,07 * e gives coherent and safe results in relation with the testing results (in EN 1993-1-3 formulas given for perforation arranged in triangle)
For the profiles without perforation calculated web crippling resistance at the end support is much lower than the experimental one. This confirms the observation in the literature that web crippling prediction formula gives very different results and considerable underestimated compared to the tests results. Only a is replaced by a = 1,07 * e.
Four Excel files were developed to provide a reliable design procedure in order to encourage and facilitate the use of profiles with perforations arranged is square. They include the calculation of span moment resistance and end support reaction and the calculation of moment-reaction interaction at internal support for profiles with perforations in the upper flange and for profiles with perforations in the web.

In practice square or circular holes in the flange of sheeting are often required for the passage of services. However, the current version EN 1993-1-3 does not provide information on how to deal with a hole in calculation of the moment resistance of the section.

A design by calculation method of profiles with a hole was developed within the GRISPE project. It is based on the results and analysis of an extensive tests programme. Global behaviour tests were performed at Karlsruhe Technical

University (KIT) in order to determine moment resistance on profiles with a hole. In this model The effective flange area is calculated according to EN 1993-1-5 with the gross cross-sectional area A_c: $A_{c,eff} = \rho A_c$ where ρ is the reduction factor for plate buckling. Both parts of the flange with a hole are considered as outstand compression elements, the reduction factor ρ is

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

The comparison of the moment resistance, with and without a hole, determined by calculation and by testing confirms that the calculation method for the resistance moment of the steel sheeting with a circular or a square hole adopted gives results that are coherent and safe in relation with the testing results.
An excel file on the calculation of span moment resistance for a profile with a hole in the upper flange has been developed to provide a reliable design procedure in order to encourage and facilitate the use of profiles with a hole.
These design by calculation methods for perforated and holed profiles were presented for proposal of Amendments on EN 1993-1-3 within CEN/TC250 Subcommittee 3 (SC3) "Steel Structures".

Mikael Blanc from Bacacier reviewed the results of the work on ***External interlocking planks and their assemblies*.**
Interlocking planks are becoming a common cladding system, mainly to match with the aesthetic considerations of architect. As many shapes of joints exist, it was decided to concentrate the GRISPE work on clip joints and chevron shape joints. These two joints can be considered to be representative of most of the products available on the market.
Eurocode EN 1993–1–3 does not offer any calculation method to evaluate the performance of such products. Thus, the aim of the project was to develop, if possible, such a calculation method.
Plank profile can be approximated to a liner tray with a simplified geometry. Therefore, the design method based on the liner tray given in EN 1993-1-3 was judged to be applicable to interlocking planks. An additional formula was needed to take into account the phenomenon of dislocation of the joint, which is a specific failure mode for such profiles (evaluation of the displacement of the joint and limitation of this displacement).
The experimental programme which was carried out in Karlsruhe in a vacuum chamber was aimed at verifying the formulas proposed in EN 1993-1-3 for wind loads (pressure and suction) resistance and to devise a method to take into account the behaviour of the plank profile regarding dislocation of the joints under wind suction loads.
Several excel sheets are available covering the bending moment resistance under pressure and suction loads, the end support shear resistance and the ultimate dislocation load.
The calculation method has been incorporate into a Eurocode amendment proposal.

David Izabel from Enveloppe Metallique du Batiment reviewed ***the proposals for the inclusion of seven calculation methods which had been submitted for inclusion into Eurocode EN 1993-1-3***.
This presentation was in the form of a question and answer session in French and English where the attendees were asked to recall the various issues which had been raised during the day and how these could form the technical basis of Eurocodes amendments.
Nine different draft clauses were envisaged for steel decks with embossments /indentations, steel decks with outwards stiffener, liner trays with s_1 >1m, assembled profiles, corrugated sheeting, curved profiles, perforated profiles, holed profiles and plank profiles.
Finally a short progress report was given of the state of play of the various amendments which had been submitted to CEN.
For the assembled profiles, discussions were ongoing in the CEN preparation group of the amendment of the EN1993 1.3 which was based on the GRISPE results, on DIN 18807, on a Swedish code for light-gauge metal structures and on EN 1090-4.
For the holed profiles, discussions were ongoing in the CEN preparation group of the amendment which merged the GRISPE approach, the German approach (reinforcement of hole) and the EN 1090-4 approach.
Other GRISPE amendments have been tabled to CEN TC 250 SC3 and are being considered as and when time allows.