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REVIEW

PhD dissertation by Mr Robert Cybulski, BSc, MSc
Title: Analysis of local stability of doubly corrugated thin-walled structures

1. The basis for the development of review

Opinion is based on the offering letter by the Dean of the Faculty of Civil Engineering of Silesian University of Technology of 31/03/2015.

2. Critical description of the dissertation

In line with established at the Faculty of Civil Engineering of Silesian University of Technology procedure the essential achievements of the dissertation are presented by the candidate at the time of the presentation, which is part of the public discussion for his thesis. For this reason, I limit myself to analyze its contents with particular attention paid to the achievement of the 8 levels of the European Qualifications Framework in terms of knowledge, skills and competence required for this level of performance outcomes, and covering the requirements of *the law on scientific degrees and scientific titles and degrees and title in the field of art*.

On the eighth level of learning according to the European Qualifications Framework, corresponding to the finalization of the third degree studies which is to defend the dissertation, it is expected the following effects:

•knowledge at the most advanced level in the field of work or study and at the crossroads of different areas;

•the most advanced and specialised skills and techniques, including synthesis and evaluation, required to solve critical problems in research or innovative activities and to broaden and specify an existing knowledge or professional practice;

•demonstrate substantial authority, innovation, independence, scientific ethics and professional and permanent involvement in the development of new ideas and processes in most contexts of work or study, including research.

The dissertation fully deserves to be assessed in the modern context of the European Qualifications Framework due to its form, content, and performance. The most important aspects include:

•to present the work in English which is the basis for scientific and social communication in the European Union. Thanks to this the dissertation and its effects have a real chance of recognition in Europe and in the world.

•Implementation of a substantial part of the research in the activities at the Silesian University of Technology in Gliwice, Poland under the National Science Center grant. This fact has placed the proposed research on National and European research levels.

A very important advantage of the dissertation is that it contains both a very professionally made analytical and numerical analysis of widely applicable structural system MIC120, combined and critically compared with extensive experimental studies used as source for very convincing verification.

It should be noted that the very idea about developing of design procedure for consideration of local buckling behaviour of doubly corrugated thin-walled panels is new and original one. The author quoted 102 reviewed items, most of them published after year 2000 and impressive list of 40 publications in this area authored and co-authored by him including some papers in international journals with good impact factor.

The clear definition of the aim and objectives of the conducted research is very beneficial, keeping in mind the extreme complexity and the wide range of problems connected with the design of thin walled systems with corrugations. Specifying the area as local stability corrugated panels under axial load helps to understand better the adopted approaches and models for solving of the connected with the area problems.

The conducted literature review is extensive and critical, with level of analysis and understanding demonstrating high level of professional knowledge, skills and abilities. The overview of existing sources is appropriately focused and structured, leading to logical conclusion about the need of the proposed specific investigation.

Both straight panels and curved panels with different radius of curvature (5, 7.5 and 10 m) are investigated. Detailed analysis of changes in material properties as result of cold-forming of the steel plates and precise geometrical description with the application of the innovative 3D optical scanning are presented.

Proposed work is generally divided on 3 main sub-areas:

- Numerical Solutions, including application of Linear Bifurcation Buckling and couple of appropriately chosen non-linear methods, namely Modified Riks Method and Stabilization Method, with appropriate development and application of combined methods in case of straight panels.
- Application of Analytical Solution Methods including important estimation of the effective widths via Von Karman, Winter and EC3 approaches. Special attention is paid to post-buckling calculation concept with estimation of the influence of the rounding of the corners and changes in material properties for detailed calculation of critical and post-critical loads for plate buckling. The analysis about the class of the discussed sections and specifically the discussion about questionable assumption for considering of doubly corrugated sections as class 4 is extremely valuable and from my point of view could be considered as important personal contribution to the science of Structural Engineering.
- The wide range of experimental investigations are planned and conducted on high professional level and adopted assumptions and approaches are appropriate. Both straight and corrugated panels are investigated with reasonable variation of loading conditions aiming clarification of the specific aspects of the behaviour of the investigated elements.

The compared results from the conducted investigation as application of above mentioned approaches and their reasonable correspondence are forming the sound basis for outlining the proposed conclusions. Again the area of research is properly and precisely specified, which helps to understand better the scope and the depth of the conducted investigation. The plans for further research are additional indication about high level of understanding and ability for research development in the indicated area.

3. Specific comments

The dissertation is written in very good English with appropriate style and very good illustrations. The graphs and tables are made with sufficient precision and good understanding about the details.

Minor improvement of the style in aspect of avoiding exceptions from 3rd person presentations, such as mentioned on several places "let us..." expressions is possible. Such expressions are fully acceptable as lecturing technique, but usually considered as not appropriate for publications and dissertations.

More detailed comments about the small differences and a bit lower values of the critical loads estimated as result of the experimental investigation in comparison with numerically estimated values both for straight and for corrugated panels would be beneficial.

Mentioned at the very end of the dissertation "Achilles heel of the doubly corrugated panels", namely the overlapping corrugation is obviously very important phenomenon and probably deserves more detailed attention at earlier parts of the proposed work. It might be the reason for the minor differences indicated in the previous paragraph.

Indicated on page 77 opinion that the flat lips are the weakest element from stability point of view might be questionable having in mind that the presented a bit later results from experimental and non-linear numerical analysis are indicating that the corrugated panel with flat lips in compression is having higher critical force than the corrugated panel with web in compression.

The above mentioned comments are not reducing the importance of the proposed work, which is very valuable and fully deserving positive appreciation.

4. Evaluation of the dissertation

Mr Robert Cybulski demonstrated outstanding ability and skills to conduct high level of research in the area of Structural Engineering showing remarkable achievements both in the areas of analytical and numerical modelling of thin walled steel structural elements and their experimental investigation. His knowledge about linear and non-linear numerical modells and their practical development using appropriate commercial software as ABAQUS is impressive and showing expertise on international level.

The analysis of the local stability problems and specifically the influence of the corrugation on the modes of failure and the estimation of the magnitude of resistance against the loss of local stability are conducted with high level of competence.

Developed comparison between classical EC3 analytical approach, the linear stability analysis and non-linear stability analysis both for cases with and without corrugations in the panels is properly structured, well discussed and convincingly supported by experimental data.

The small and the large scale experimental investigations are conducted with professional knowledge and understanding about the instrumentation, precision and quality of the obtained data and the techniques for detailed analysis of the results with attention to the wide range of possible influencing factors.

The proposed final conclusions, namely the confirmation of class 4 for the straight panel's section, the proof that corrugated panel's section is not class 4, the proof that neglecting corrugations could lead to overestimation of the ultimate loads and that the starting point for calculation procedures for doubly corrugated structures has been provided are fully acceptable.

In conclusion the candidate possessed the knowledge, skills and competences needed to meet fully the requirements placed on the eighth level of learning according to the European Qualifications Framework.

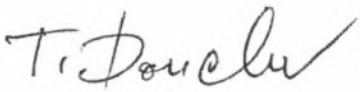
5. Conclusion

I consider that as conclusion based on presenting of the above mentioned views and comments the reviewed thesis satisfies the requirements *of the Act about scientific degrees*

and scientific titles and degrees and titles in the field of art of 14 March 2003 (OJ 2003, no. 65, item 595) and its subsequent amendments. In accordance with article No. 4.13 of this Act the dissertation presents an original solution to the problem of science, shows a general theoretical knowledge in the discipline of candidate via his research and the ability to conduct independent scientific work in the area of Structural/Civil Engineering and Construction.

In this connection I support the acceptance of the candidate's dissertation and granting a permission to Mr. Robert Cybulski to conduct public discussion over his dissertation.

Signature:



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