CELLULAR BEAM-COLUMNS IN PORTAL FRAME STRUCTURES

Plan of action

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PREFACE

This document serves as a plan of action for the work I hope to do for the Master thesis: *Cellular beam-columns in portal frame structures*. The Master thesis will be done in partial fulfilment of the requirements of the programme of Civil Engineering, section Steel and Timber Structures at Delft University of Technology.

Although already a large deal of research has been carried out on the behaviour of (non)-composite cellular beams, almost no attention was paid to the application of cellular members as columns. Especially the use in portal frame structures seems attractive. Therefore this research is devoted to the behaviour of cellular beam-columns.

The first phase of this project will be carried out at the Research Centre of Arcelor Profil Luxembourg in Esch-sur-Alzette, Luxembourg. The work of the second phase will take place at Ingenieursburo voor Bouwtechniek (IBT), a firm of consulting engineers in Veenendaal, The Netherlands. I would link to thank respectively O. Vassart and Ir. A. 't Land for giving me those possibilities. Furthermore, I would like to express my gratitude to the other persons of the thesis committee: Prof. Ir. F.S.K. Bijlaard, Dr. A. Romeijn and Dr. Ir. P.C.J. Hoogenboom.

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1 INTRODUCTION

Cellular members – steel I-shaped structural elements with circular web openings at regular intervals – have been used as beams for more than 20 years now. However, in certain countries, like the Netherlands and Belgium, application seems to lack behind. This is probably due to both unfamiliarity with these beams, and a lack of localised design guides for practise. Cellular columns are less common, but examples are available. However, in research publications no attention is paid to this topic. Structural engineers have to base their estimates on simplified methods of analysis and good engineering judgement. Therefore, a desire for a more refined approach exists.

Figure 1 Service integration through openings

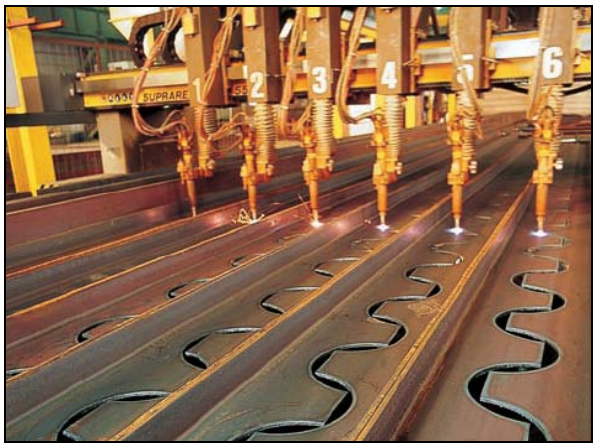

Figure 2 Fabrication by flame cutting of hot-rolled profiles

The subject of cellular members came to my attention mainly because of two reasons. Firstly, an open thesis subject was available for researching the possibility of using plate girders with circular openings in bridges. Secondly, at the firm of consulting engineers where I did my practical, Ingenieursburo voor Bouwtechniek, they once applied cellular columns in a car showroom. Because of a lack of existing design guidance, they had to find their own way in making the calculations. Probably these were quite conservative. Knowing this, I thought it to be worthwhile to get a more refined prediction of the capacity of these members.

In my search for information on the subject of cellular members I contacted Ir. J. Naessens from the Staalinfocentrum in Belgium. He advised me to get in touch with some people within Arcelor, a worldwide operating steel company. This resulted in an offer to carry out the research at Arcelor Research Centre. One consideration of particular interest was that to make reliable predictions based on FEM calculations, real test data is needed to calibrate the models. Because these test results are confidential, and the calculation model to be proposed needs to be verified, it was decided that it would be best to carry out a part of the research work at Arcelor's offices.

In this document a general overview is presented of the work that the Master thesis will involve. After this introduction a broad outline is given of the topics the literature study will deal with. Then the importance of the numerical research to be done is explained. Finally the planning of the total thesis is presented.

2 LITERATURE STUDY

2.1 Introduction

The thesis will start with a literature study to gain knowledge about the structural behaviour and the applications of cellular beam-columns. Production methods and the current research status will also be discussed. The following paragraphs indicate the most important parts of the literature study.

2.2 Mechanical behaviour

In this part of the literature study the observed behaviour of cellular members under real loading tests will be discussed. Extensive attention will be given to the failure mechanisms that may occur. The existing design method for cellular beams will be described and criteria will be given by which the design has to be tested. Furthermore the similarities and differences in behaviour with full cross-sectional members will be pointed out.

2.3 Standards and guidelines

Several guidelines on the behaviour and calculation of cellular beams are published. The most recent and relevant publications are discussed. Furthermore it will be investigated to what detail guidance is offered by the existing standards. The attention is in particular focussed on the upcoming European standards, whereof *Eurocode 1 – Actions on structures* [EN1991-1-1] and *Eurocode 3 – Design of steel structures* [EN1993-1-1] are most important for the present investigation.

3 NUMERICAL RESEARCH

From the literature study it shall become clear what knowledge is available on the behaviour of especially beam-columns. It is anticipated already that analytical and numerical investigations are needed to provide a better understanding of the behaviour of cellular beams-columns and to give guidance for design. Therefore calculations models have to be proposed and verified by FEM calculations which are calibrated against real test data. Due to the large influence of initial deformations on the occurrence of local instabilities, the existence of validated numerical results is crucial.

4 CASE STUDY

This last phase will be carried out at the office of Ingenieursburo voor Bouwtechniek. In this part a case study will be carried out. The case study will provide a fully worked out calculation of a portal frame using cellular members. It is expected that hereto a software tool in Excel will be set up. From this study the practical implications of using cellular beams in portal frame structures should become clear. The concluding report shall be able to serve as a manual to structural engineers for the design of portal frames using cellular beams-columns.

5 PLANNING

Recognizing that 30 weeks are planned for the Master thesis, the project can be finished at the end of September 2007. The initial search for a suitable Master thesis subject started in November 2006. At that moment it was not clear yet what the topic would be. Out of a few possibilities it was decided to work on the topic of cellular beams. At first it seemed that the research would have an evaluative character, comparing these beams with other structural solutions. However at a later stadium Arcelor became involved, and the possibility to carry out part of the research at their office in Luxemburg changed this into the present subject . Therefore it took some time to get really started. In the mean time quite a lot of information has been gathered, so the literature study now should not take more than a few weeks anymore.
After this study, the main phase of the thesis can start: the development of a calculation model for the design of cellular beam-columns. The proposed model has to be verified against FEM calculations. With this model, in the last phase of the project an case study will be carried out.
The first phase will take place at Arcelor Research Centre. After the numerical research, a presentation is planned. Subsequently the second phase will take place at Ingenieursburo voor Bouwtechniek, starting from July. During the whole project intensive contact will be maintained with the daily guide, Dr. A. Romein.

The table below presents this global planning.

	Time (weeks)																												
	March				April					May				June				July					August					September		
Activities	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Plan of action																														
Initial assessment																														
Literature study																														
Numerical research																														
Intermediate presentation																														
Case study																														
Writing final thesis report																														
Final assessment																														

During the yellow colored weeks the research will be carried out at Arcelor.

REFERENCES

Brochures

ACB 2006 Arcelor Cellular Beams – The intelligent solution for long spans. *Arcelor Commercial Sections S.A.* Edition 2006-1.

Standards

EN1991-1-1 Eurocode 1: Actions on structures – *Part 1-1: General actions – Densities, self-weight, imposed loads for buildings*. . CEN – European Committee for Standardization. April 2002.

EN1991-1-3 Eurocode 1: Actions on structures – *Part 1-3: General actions – Snow loads*. . CEN – European Committee for Standardization. July 2005.

EN1991-1-4 Eurocode 1: Actions on structures – *Part 1-4: General actions – Wind actions*. CEN – European Committee for Standardization. April 2005.

ENV1993-1-1 Eurocode 3: Design of steel structures – *Part 1-1: General rules and rules for buildings*. CEN – European Committee for Standardization. April1992.

Annex N Eurocode 3: Design of steel structures – *Part 1-1: General rules and rules for buildings*. *Amendment A2: Annex N* – Openings in Webs. British Standards Institution. 1993.

EN1993-1-1 Eurocode 3: Design of steel structures – *Part 1-1: General rules and rules for buildings*. CEN – European Committee for Standardization. May 2005.

EN1993-1-5 Eurocode 3: Design of steel structures – Part 1-5: Plated structural elements. CEN – European Committee for Standardization. October 2006.

Websites

www.arcelor.com/sections
Arcelor Commercial Sections S.A.
www.bouwtechniek.nl
Ingenieursburo voor Bouwtechniek

ANNEX A ARCELOR PROFIL LUXEMBOURG

Arcelor was created in 2002 by the fusion of the French company Usinor, the Luxembourg ARBED en the firm Spanish Aceralia. Following the merger with the Indian company Mittal Steel in 2006 the world's largest steel producer was formed, Arcelor Mittal, with 330,000 employees in more than 60 countries.

In Europe it covers the industrial, marketing and sales activities for beams, channels and heavy merchant bars with Arcelor Commercial Sections, a Product Unit of the Long Carbon Steel Europe Business Unit. The majority of Arcelor Commercial Sections' products and solutions are used in the construction industry, the mechanical and the transportation sectors.

The Research Centre of Arcelor Profil Luxembourg aims at developing new and innovative products and solutions to meet the specific needs of the markets. In cooperation with the Marketing and Technical Assistance teams special softwares for the Arcelor products are produced. Numerous areas are investigated, with special attendance for fire safety engineering, composite construction, earthquake resistance, etc. Its reports are distributed in conjunction with European technical and promotional organisations. Hereby close relations are maintained with various universities and technical centres.

ANNEX B INGENIEURSBUREAU VOOR BOUWTECHNIEK

Since 1968 Ingenieursburo voor BouwTechniek (IBT) is an independent firm of consulting engineers servicing architects, building contractors and individual clients. IBT is located in Veenendaal and Papendrecht in The Netherlands.

IBT provides its clients with:

- structural designs including technical drawings in steel, concrete and timber;
- advices for renovation;
- calculations of EPN , ventilation and daylight;
- fire safety engineering calculations.

The team of IBT consist of over 20 employees, which are continuously developing their skills by means of additional courses and their daily work experiences.

The main areas of activity are:

- residential, commercial and industrial building;
- houses, apartment buildings and shopping complexes;
- industrial facilities;
- schools and churches.

Furthermore IBT is involved in developing pre-stressing configurations for a manufacturer of precast concrete structural elements.

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