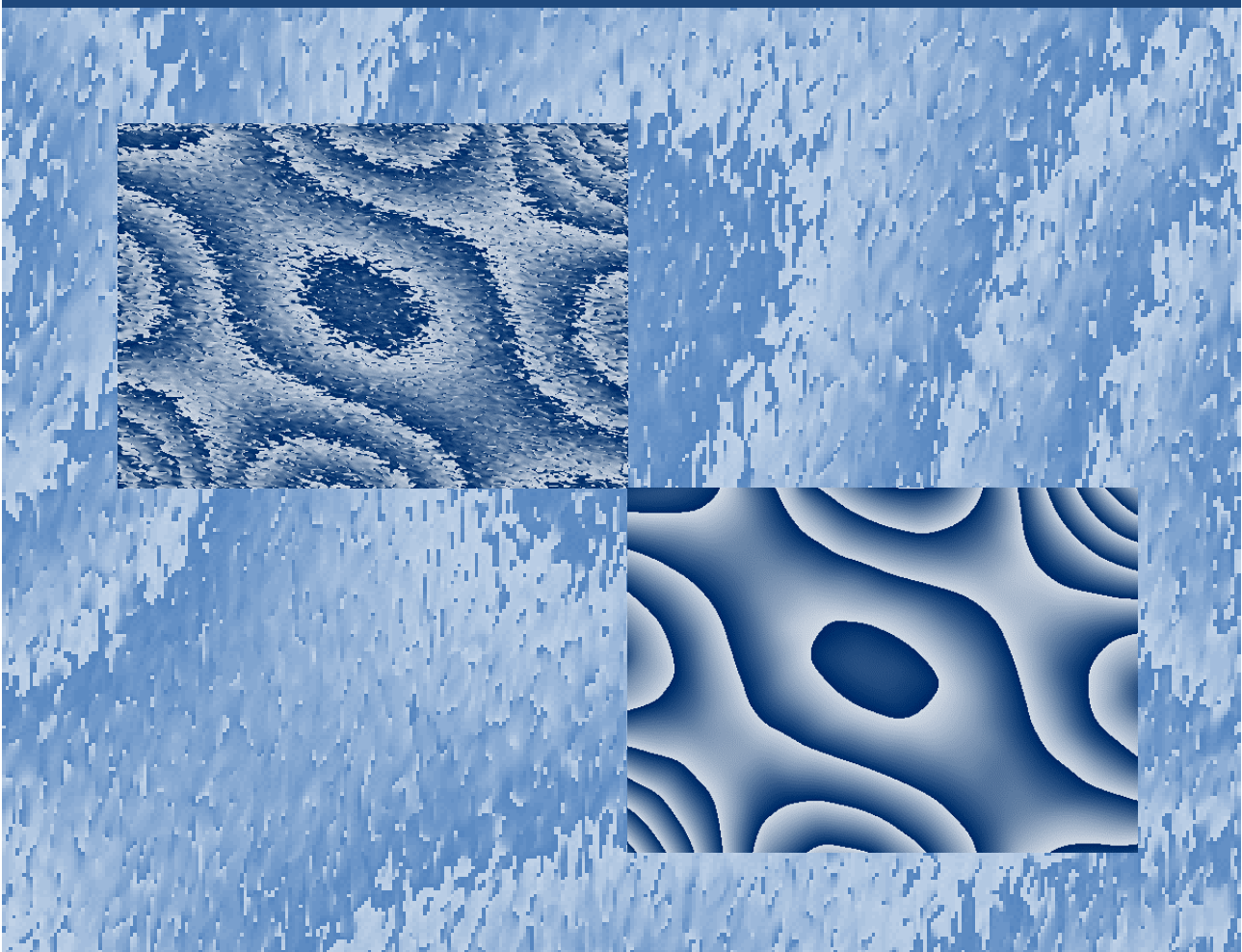


EXPERIMENTAL MECHANICS

New Trends and Perspectives

J.F. Silva Gomes, Mário A.P. Vaz
Editors



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(NEW TRENDS AND PERSPECTIVES)

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J.F. Silva Gomes, Mário A.P. Vaz (Ed)

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PREFACE

Engineering practice in general and mechanical design in particular are basically exercises of creativity, triggered by specific needs. As the engineering community continues to cross the boundaries of known practices, design and manufacturing techniques into the frontiers of new materials and mechanical systems, energy sources and their effects upon the environment, the opportunities for failure will inevitably increase. If our knowledge of how to engineer systems, structures and components to minimize or prevent failure is to keep pace with modern demanding applications and the intolerance of a safety conscious society, we must develop and apply superior analytical and experimental tools to evaluate the potential for damage or failure of engineering structures and/or components and the associated energy harvesting systems.

Different tools are available to optimize any engineering solution, from which *Experimental Mechanics* has always played a most prominent role. It is related to such diverse disciplines as physical and mechanical sciences, engineering (mechanical, aeronautical, civil, automotive, nuclear, etc.), materials, electronics, medicine and biology, and uses experimental methodologies to test and evaluate the behaviour and performance of all kinds of materials, structures and mechanical systems. Quality control, safety, destructive and non-destructive testing of materials and components, analysis of prototypes and even fundamental research are some of the possible applications of *Experimental Mechanics*. During the last few decades the development of computer based techniques, as well as laser-optics methods, nanotechnologies and nanomaterials, among many other technological advances, added new dimensions and perspectives to *Experimental Mechanics and Testing*.

This volume contains the extended Abstracts of the 564 papers accepted for presentation in the ICEM15-15th International Conference on Experimental Mechanics held in Porto/Portugal, 22-27 July 2012. It is complemented by an accompanying CD-ROM containing the full length text of the papers. The book is organized in three main parts: PART-A, with the abstracts of the 11 Invited Plenary Papers, by distinguished academics and scientists in the field of *Experimental Mechanics*; PART-B, with 289 abstracts distributed by the 12 general main topics (from A to L); and PART-C, with the remaining 264 abstracts from the 20 Special Symposia in ICEM15.

The ICEM15 conference is part of a prestigious series of conferences that was initiated in 1959, in Delft (The Netherlands), and the last one took place in Poitiers (France) in July 2010. All these *Experimental Mechanics* meetings resulted from the belief that of those disciplines associated with advanced product design and manufacture, experimental mechanics techniques have been making continuous and significant advances during the years. Important and dramatic improvements in systems and components design can be made by the use of the latest advances in experimental mechanics techniques applied to energy systems, structures and materials. Their effect on the environment is significant and will help in avoiding global warming and harmful CO₂ emissions.

It is organized by the Faculty of Engineering of the University of Porto (FEUP) and the Portuguese Association for Experimental Mechanics (APAET), under the auspices of the European Association for Experimental Mechanics (EURASEM), and sponsored by a number of national and international organizations, whose support is gratefully acknowledged: SEM-

American Society for Experimental Mechanics, BSSM-British Society for Strain Measurement, JSME-Japanese Society of Mechanical Engineering, IMEKO-International Measurement Confederation, AFM-Association Française de Mécanique, DYMAT-European Association for Dynamics of Materials, INEGI-Instituto de Engenharia Mecânica e Gestão Industrial, LABIOMEPP-Laboratório de Biomecânica do Porto, LNEC-Laboratório Nacional de Engenharia Civil, FCT-Fundação para a Ciência e a Tecnologia, FCG-Fundação Calouste Gulbenkian, FLAD-Fundação Luso-Americana para o Desenvolvimento, CCDRN-Comissão de Coordenação e Desenvolvimento Regional do Norte, ABEU-PCO, Professional Congress Organizer, and Teatro Nacional S. João/Secretaria de Estado da Cultura.

We are particularly indebted to all *Symposium Promoters* for the coordination of the different themes and to the authors for their papers and presentations. The different contributions during the conference offered opportunities for thorough discussions with the authors. We acknowledge all of the participants, who contributed with innovations, new research approaches, novel techniques and testing methodologies, and their invaluable critical comments.

We are also indebted to the eleven outstanding *Plenary Lecturers* who highlighted the conference themes with their contributions: Dr. Shaker A. Meguid (University of Toronto/Canada), Dr. Gustavo B. Guimarães (Manufacture Engineering, EMBRAER/Brazil), Dr. Yoshiharu Morimoto (Moire Institute Inc., and Wakayama University, Wakayama, Japan), Dr. Emmanuel Gdoutos (Democritus University of Thrace, Greece), Dr. Robert A.W. Mines (University of Liverpool, United Kingdom), Dr. Sergei T. Mileiko (Russian Academy of Sciences, Russia), Dr. Michael B. Prime ((Los Alamos National Laboratory, USA), Dr. Mário A.P. Vaz (University of Porto, Portugal), Dr. Josef Eberhardsteiner (Vienna University of Technology, Austria), Dr. José Ygnacio Pastor (Technical University of Madrid, Spain), and Dr. Alfredo L. Campos (LNEC, Portugal).

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J.F. Silva Gomes and Mário A.P. Vaz

Porto, July 2012

PAPER REF: 2809

EXPERIMENTAL TESTS OF PARTIALLY ENCASED BEAMS AT ELEVATED AND ROOM TEMPERATURE

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ABSTRACT

This work presents the experimental tests developed on partially encased beams (PEB) at elevated temperature. PEB were built with IPE100 steel profile. Two beam lengths were tested (2.5 and 4 m) at 20, 400 and 600 °C. Seven series were tested to compare the performance of PEB using two different stirrups conditions (welded and not welded to web). The behaviour of IPE 100 PEB was also compared with IPE 100 steel bare at room temperature. Most of the beams attained the ultimate limit state by lateral torsional buckling (LTB), with exception for those tested at 600 °C which collapsed by the formation of a plastic hinge (PH). The ultimate load of PEB increased 85% in comparison with steel bare at room temperature. A decrease in the ultimate load of 24% and 22% was verified when temperature increased from 20 to 400 °C and from 400 °C to 600 °C, respectively. The bending resistance of PEB without welded stirrups, tested at 400 °C, decreased between 4% and 15 % with respect to PEB with welded stirrups, for beam lengths of 2.4 and 4.5 m, respectively.

INTRODUCTION

Partially Encased Beams (PEB) are defined from a steel profile, usually I-Shape or H-shape cross section, using reinforced concrete between flanges. Concrete between flanges increases fire resistance, load bearing and stiffness, without enlarging the overall size of steel bare cross sections. These advantages outweigh the increasing self-weight of the partially encased solution.

Partially Encased Beams (PEB) have been widely tested at room temperature but only a small number of tests have been developed under fire or elevated conditions. The most relevant tests were developed by Kindmann *et al* (Kindmann *et al*, 1993), proving the importance of the reinforced concrete between flanges for bending resistance, Lindner and Budassis in 2000 (Lindner *et al*, 2000) developed a new design proposal for lateral torsional buckling, and Maquoi *et al* (Maquoi *et al*, 2002), improved the knowledge on the elastic critical moment and on the lateral torsional buckling resistant moment. A small number of 15 experiments were developed on PEB under fire conditions (small series) and are reported by authors in a previous work (Piloto *et al*, 2011).

A new set of 16 bending experiments were developed at elevated temperature, using intermediate and large scale elements, see table 1. Room temperature tests were developed with incremental load. High temperature tests used electro-ceramic resistances applied to beam flanges, with a heating rate of 800 [°C/h] up to the specified temperature level. Supports were adjusted and load was applied after temperature stabilization (60 or 90 minutes after the start of heating).

Table 1 List of tested beams

Series	Specimen	Stirrups	Temp. [°C]	Max. lat. Imper.[mm]	Fu - Ultimate Force [N]	Fu [N] (average)	Failure mode
1	B/2.4-02	W	400	2	31603	32570	LTB
	B/2.4-03			2	33538		
2	B/2.4-07	NW	400	1	29000	31121	LTB
	B/2.4-09			1	33242		
3	B/3.9-01	W	400	2	30204	28585	LTB
	B/3.9-02			5	27290		
	B/3.9-03			3	28337		
4	B/3.9-04	W	600	2	22456	22296	PH
	B/3.9-05			2	21662		
	B/3.9-06			5	22770		
5	B/3.9-07	NW	400	5	23524	24098	LTB
	B/3.9-09			2	24672		
6	B/3.9-11	W	20	2	38718	37431	LTB
	B/3.9-12			5	36187		
7	B/3.9-11A	-	20	1	19369	20186	LTB
	B/3.9-12A			3	21037		

RESULTS AND CONCLUSIONS

Sixteen four-point bending tests were performed to evaluate the bending resistance of partially encased beams at room and elevated temperature.

Force displacement results are presented to compare the bending resistance. Strain was recorded to acknowledge the elastic and plastic behaviour of the mid cross section. Temperature evolution demonstrates the stationary thermal state during loading.

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