Faculty of Engineering, University of Porto

IRF'2009, Porto 20-24 July 2009

INTEGRITY RELIABILITY AND FAILURE

CHALLENGES AND OPPORTUNITIES

Editors:

J.F. Silva Gomes

Shaker A. Meguid

Published by

INEGI-Instituto de Engenharia Mecânica e Gestão Industrial
Rua Dr. Roberto Frias, 4200-465 Porto, Portugal
Tel:+351 22 957 87 10; Email: inegi@inegi.up.pt
www.inegi.up.pt

July, 2009

ISBN: 978-972-8826-22-2
Legal D.N: 295639/09

Printed by:

LusoImpress (Grupo Claret)
Rua Venceslau Ramos, s/n – 4430-929 Avintes, Portugal
Tel:+351 22 787 73 20; Fax:+351 22 787 73 29

IRF'2009

INTEGRITY, RELIABILITY AND FAILURE
(CHALLENGES AND OPPORTUNITIES)

Editors

J.F. Silva Gomes and Shaker A. Meguid

Edições INEGI
(2009)

ORGANIZATION

Faculty of Engineering, University of Porto

LOCAL ORGANIZING COMMITTEE

J.F. Silva Gomes and Shaker A. Meguid, (*Co-Chairs*)

Carlos C. António, José M. Cirne, Rui M. Guedes, Paulo G. Piloto
M. Teresa Restivo, Aarash Sofla, Mário A.P. Vaz

INTERNATIONAL SCIENTIFIC COMMITTEE

Clito F. Afonso, *Portugal*; Anabela C. Alves, *Portugal*; C.C. António, *Portugal*; Rui C. Barros, *Portugal*; K.J. Bathe, *USA*; R. de Borst,*Netherlands*; Pedro Camanho, *Portugal*; Carlos Cardeira, *Portugal*; Catarina Castro, *Portugal*; J.L. Chenot, *France*; *Luisa Costa*, Portugal; Álvaro Cunha, *Portugal*; S. Datta, *USA*; J. Rodrigues Dias, *Portugal*; José L. Esteves, *Portugal*; A.J.M. Ferreira, *Portugal*; Elza Fonseca, *Portugal*; Hossam A. Gabbar, *Canada*; S.V. Hoa, *Canada*; I. Hutchings,*UK*; N. Jones, *UK*; Renato N. Jorge, *Portugal*; David Kennedy, *Ireland*; H.W. Klein, *Germany*; M. Langseth, *Norway*; T. Laursen,*USA*; Celina P. Leão, Portugal; R. Lewis, *UK*; D.G. Lee, *Korea*; Nuno Maia, *Portugal*; A. Mal, *USA*; A.T. Marques, *Portugal*; J. Couto Marques, *Portugal*; Alberto Meda, *Italy*; S. A. Meguid, *Canada*; R.E. Miller, *Canada*; G. Mimmi, *Italy*; Rosa M. Miranda, *Portugal*; Y. Miyano, *Japan*; Amiram Moshaiov, *Israel*; Marcelo F. Moura, *Portugal*; Carlos Navarro, *Spain*; C. Papalettere, *Italy*; Paulo Piloto, *Portugal*; J.N. Pires, *Portugal*; J.N. Reddy, *USA*; M.T. Restivo, *Portugal*; Nuno F. Rilo, *Portugal*; J. Dias Rodrigues, *Portugal*; C.Q. Ru, *Canada*; Arlindo J. Silva, *Portugal*; Lucas F.M. Silva, *Portugal*; J.F. Silva Gomes, *Portugal*; C.A. Sciammarella, *Italy*; Jorge H.O. Seabra, *Portugal*; M. Gameiro Silva *Portugal*; S. Carmo Silva *Portugal*; C. M. Soares, *Portugal*; Afzal Suleman, *Portugal*; João M.R.S. Tavares, *Portugal*; M.J . Tooren, *Netherlands*; K.T. Tan, *Singapore*; Mário P. Vaz, *Portugal*; George Weng, *USA*; Y.C. Yoon, *Singapore*; Z. Zhang, *China*.

SYMPOSIA COORDINATORS

Clito Afonso *(U. Porto, Portugal)*, Carlos C. António *(U. Porto, Portugal)*, Tiago Barbosa *(IPB, Portugal)*, Rui C. Barros *(U. Porto, Portugal)*, Pedro Camanho *(U. Porto, Portugal)*, J. Reis Campos *(U. Porto, Portugal)*, M. Braz César *(IPB, Portugal)*, J. Rodrigues Dias *(U. Évora, Portugal)*, José S. Esteves *(U. Porto, Portugal)*, Paulo Fernandes *(IST, Portugal)*, António Ferreira (U. Porto, Portugal), Elza Fonseca *(IPB, Portugal)*, Mihail Fontul *(IST, Portugal*, Hossam Gabbar *(UOIT, Canada)*, J.F. Silva Gomes *(U. Porto, Portugal)*, Renato N. Jorge *(U. Porto, Portugal)*, Jackie Li *(CUNI, USA)*, F. Jorge Lino *(U. Porto, Portugal)*, Ramiro Martins *(INEGI, Portugal)*, Alberto Meda *(U. Rome, Italy)*, Shaker A. Meguid *(U. Toronto, Canada)*, Rosa Miranda *(FCT/UNL, Portugal)*, Paulo Piloto *(IPB, Portugal)*, M. Teresa Restivo *(U. Porto, Portugal)*, Nuno Rilo *(U. Coimbra)*, J. Dias Rodrigues *(U. Porto, Portugal)*, Carla Roque *(U. Porto, Portugal)*, Jorge Seabra *(U. Porto, Portugal)*, Arlindo Silva *(IST, Portugal)*, Lucas F. Silva *(U. Porto, Portugal)*, Aarash Sofla *(U. Toronto, Canada)*, João M. Tavares *(U. Porto, Portugal)*, César Vasques *(INEGI, Portugal)*, Mário A.P. Vaz *(U. Porto, Portugal)*, Zheng Hong Zhu *(York U., Canada)*.

CHAPTER XVIII

SYMPOSIUM

STRUCTURAL SAFETY

Coordinated by

Paulo A.G. Piloto[1(*)] and Alberto Meda[2(*)]

[1]*Instituto Politécnico de Bragança, Portugal*
[2]*University of Rome, Italy*

In Association with

IRF'2009

3rd International Conference on Integrity, Reliability and Failure

Porto, Portugal
20-24 July 2009

Editors

J.F. Silva Gomes	Shaker A. Meguid
Faculty of Engineering	*MADL*
U.Porto, Portugal	*U.Toronto, Canada*

(*) Associate Editors for the papers in this Chapter

Introduction to Symposium on Structural Safety

Safe design is a design process that eliminates hazards, or minimizes potential risks, by involving decision makers and considering the life cycle of structures and materials. Safe design approach will generate a well-informed design option that should eliminate these potential problems to those who makes the product and to those who use it.

Structural safety in design will cover the design aspects of safe structures and components, using different materials. Advances in standards and regulations should permanently ensure safety with the best practices and methods. Advanced analysis methods should be permanently improved and used to prevent such potential risk in structures and materials. Designers should guarantee structural integrity and reliability.

The following communications will present different aspects in Damage Analysis and Assessment, Fire Safety Engineering, Life Cycle Analysis, Natural and Man-Made Hazards, Performance-Based Design Methods, Prescribed Design Methods, Computational Methods and Simplified Methods for Structural Safety.

Paulo Piloto
Instituto Politécnico de Bragança
Alberto Meda
University of Rome "Tor Vergata"

REF: S2004_A0472

INELASTIC BEHAVIOUR OF PARTIALLY ENCASED SECTIONS - NUMERICAL COMPARISON

P.A.G. Piloto[1(*)], AnaRamos Gavilán[2], L.MR. Mesquita[1], and Alberto Meda[3]
[1]Polytechnic Institute of Bragança, Portugal
[2]University of Salamanca, Zamora, Spain
[3]University of Rome "Tor Vergata", Rome, Italy
[(*)]*Email:* ppiloto@ipb.pt

SYNOPSIS

Partially encased sections are made of composite steel and concrete casted between flanges. They present an attractive solution in comparison with bare steel or reinforced concrete counterparts. This paper intends to validate experimental results for bending and axial loading members at room temperature, (Elghazouli et al, 2008). The experiments were conducted at the Imperial College in London and aimed to provide essential data for validating future analytical and design studies. This numerical comparison is based on three dimensional finite element modelling, simulating bond contact and failure of concrete. The numerical results agree well with experimental results.

INTRODUCTION

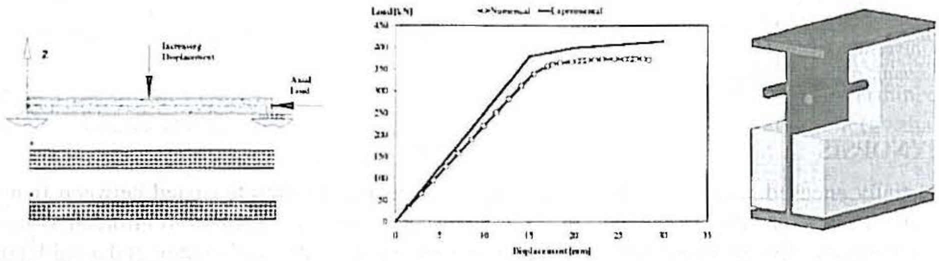
The additional weight introduced by concrete is counterbalanced by the increasing stiffness. This advantage has enabled this section to be used into different types of construction, such as buildings or car parking, tested for natural and accidental conditions. In Europe, the use of partial rather than full encasement of steel profiles has proved more popular in recent years. Partially encased members have also been initially introduced as a means of improving fire behaviour.

This paper deals with the inelastic performance of partially-encased members at room temperature conditions, which are detailed according to conventional European practice (CEN-EN 1994-1-1, 2004). The model presented in figure 1 consists of an HEA200, high grade steel S460, with an equivalent C40/50 concrete. Concrete reinforcement used 8 [mm] rebar B500. The experiment referenced with C20Y0 was performed without axial load.

The experimental setup was designed with a hydraulic actuator for increasing vertical displacement under quasi-static loading conditions. The support and loading points were also used to provide out-of plane restraint for the experiments. Wide flexural cracks characteristic of pure bending behaviour were observed in the concrete portion, extending throughout most of the member depth.

An evaluation of the yield point of the member is required for assessing the effective stiffness, capacity and ductility of a member. For reinforced concrete members the first yielding of the reinforcement bars is assumed to represent this state. For steel members the first yield is not normally followed by significant increase in curvature, but the plastic hinge normally represents its ultimate limit state. For partially encased section, a plastic hinge may be attained with fully plastic steel section and with concrete completely damaged.

The numerical analysis is based on ANSYS three dimensional finite element model, (Ansys INC, 2008). One part of the mesh was generated with finite shell elements to represent the steel profile and the other mesh part modelled with solid and link elements to represent reinforced concrete. These elements share common nodes, so that no movement between concrete and reinforcement was considered. These meshes were joined by non-linear finite spring elements used to simulate bond interface behaviour. The mechanical analysis required material and geometrical non-linear solutions to simulate large displacement with a maximum and minimum incremental displacements of 1,4 and 0.014 [mm], respectively.



a) b) c)

Fig. 1 Tested model C20Y0 (HEA 200). a) Prediction of concrete failure; b) Result comparison; c) Section.

An elastic - plastic model with strain hardening behaviour was considered for steel, using the suitable experimental values. Concrete being quasi brittle material was simulated with different behaviour for compression and tension, using stress relaxing model to improve numerical convergence. The presence of a crack at an integration point is represented through modification of the stress-strain relations by introducing a plane of weakness in a direction normal to the crack face. If the material, at an integration point, fails in uniaxial, biaxial, or triaxial compression, the material is assumed to crush at that point. In addition to cracking and crushing, the concrete may also undergo plasticity. In this case, the plasticity is verified before the cracking and crushing checks, (Ansys INC, 2008).

Triaxial confinement of concrete may produce direct influence in the behaviour of partially encased sections, by considerable improvement of mechanical properties, (Elghazouli et al, 2008). This phenomenon was considered during numerical simulations.

CONCLUSIONS

Numerical comparison is presented for experiments conducted at the Imperial College in London. Results agree well for the first yield point and ultimate limit state. The numerical model captures all the major and relevant state modification for partially encased sections.

REFERENCES

[1] A.Y. Elghazouli, J. Treadway. Inelastic behaviour of composite members under combined bending and axial loading. Journal of Constructional Steel Research, 64, 2008, p. 1008–1019.

[2] CEN - EN 1994-1-1. Eurocode 4: Design of composite steel and concrete structures - Part 1-1: General rules and rules for buildings. Brussels, December 2004.

[3] Ansys INC. ANSYS Academic version. Release 11.0, Help System, 2008.

About the Book

As the engineering community continues to cross the boundaries of known practices, materials and manufacturing techniques into the frontiers of new functional materials, environments and applications, the opportunities for catastrophic failures will inevitably increase. If our knowledge of how to engineer systems, structures and components to minimize or prevent catastrophic failure is to keep pace with modern manufacturing technologies, the demanding applications, and the intolerance of a safety conscious society, we must continue our efforts to develop and use superior materials, apply reliable analytical techniques and validate these with sound experimental tools.

This book contains the Abstracts of papers presented at the 3rd International Conference on Integrity, Reliability and Failure, held at the Faculty of Engineering, University of Porto, Portugal, 20-24 July 2009. This is part of a prestigious series of Integrity Reliability and Failure conferences coordinated by the International Scientific Committee on Mechanics and Materials in Design. The conference attracted over 260 participants with 310 accepted academic and industrial submissions from 45 different counties around the world. These papers were presented in July 2024, 2009 in the ma gnificent city of Porto, Portugal, and the conference themes focused on design, nanotechnology, advanced materials, computational and structural mechanics, experimental mechanics, structural safety, energetic systems, and case studies.

EDIÇÕES INEGI