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DEPARTMENT OF CIVIL, CHEMICAL AND ENVIRONMENTAL ENGINEERING
POLYTECHNIC SCHOOL OF THE UNIVERSITY OF GENOVA, ITALY

CURRICULUM of the RESEARCH ACTIVITY

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SUMMARY

Marco Lepidi was born in L'Aquila, Italy. Marco graduated from high school with full marks at the Liceo Classico of L'Aquila, Italy (july 1996). He received a five-year degree in Civil Engineering (110/110 cum laude) from the University of L'Aquila, Italy (july 2002), and a Ph.D. in Structural Engineering from the University of Rome "La Sapienza", Italy (may 2006).

Marco is currently Associate Professor for the Academic Discipline ICAR/08 - Structural Mechanics[1] at University of Genova, Italy (from june 2018), where he presently joins the DICCA - Department of Civil, Chemical and Environmental Engineering. Formerly, Marco has been Assistant Professor at the University of Genova, Italy (from september 2012 to may 2018). In may 2019 Marco obtained the National Scientific Qualification (ASN) to function as Full Professor for the Academic Discipline ICAR/08 - Structural Mechanics.

Marco is being continuously involved in research activities since 2002. His principal research interests focus on theoretical and applied topics of Solid and Structural Mechanics, including: (i) *linear and nonlinear dynamics of structures*, (ii) *mechanics of periodic microstructured materials and acoustic metamaterials*, (iii) *eigensensitivity and stability analysis of resonant dynamic systems*, (iv) *dynamic identification of physical, modal and damage parameters*, (v) *structural health monitoring and vibration control*, (v) *earthquake engineering*.

Marco authored or co-authored more than 130 scientific publications, including articles published in international (35) and Italian journals (4), book chapters (7), papers included in proceedings of international (49) and national conferences (30). The impact of this scientific production is measured by the citations: 881 (SCOPUS), 657 (ISI WEB OF SCIENCE), 1189 (GOOGLE SCHOLAR), corresponding to the H-index: 17 (SCOPUS), 15 (ISI WEB OF SCIENCE), 19 (GOOGLE SCHOLAR). One of the journal papers has been awarded with the IASCM Takuji Kobori Prize (2014).

Marco is Assistant Editor of the scientific journal MECCANICA (Springer, from october 2014), and is member of the Editorial Board for the scientific journals SPRINGERPLUS (Springer, from june 2015), COUPLED SYSTEMS MECHANICS (TechnoPress, from september 2015), 4OPEN (EDP Sciences, from june 2017) and SHOCK AND VIBRATION (Hindawi, from march 2018). Marco regularly serves as peer reviewer for more than 40 scientific journals (PUBLONS). He has participated in the organizing committee for national and international conferences, as well as for advanced training courses. Marco is currently affiliated to Centers of Excellence (DEWS), and is member of scientific associations and societies (EACS, EUROMECH, AIMETA, SISCO, ANIV, GADES).

Marco participated in the Research Unit of the Universities of L'Aquila and Genova for several research projects in the field of structural mechanics, funded by national authorities (MIUR-PRIN, RELUIS-DPC) and local agencies (CARISPAQ-MIVIS, UNIGE-PRA, UNIGE-FRA). Marco was awarded with four Marie Curie Fellowships for the participation to advanced training courses and international conferences in the framework of the FP6 Marie Curie Action project SICON.

Marco has been repeatedly involved in the scientific activities developed at european research centres, with the role of Research Fellow at the Earthquake Engineering Research Centre of the University of Bristol, England (2003), and Visiting Ph.D. at the Structural Engineering Research Laboratory of the EMPA Swiss Federal Laboratories at Zurich, Switzerland (2005).

From the XXXIII cycle, Marco is member of the Teacher Committee for the Ph.D. program in Civil, Chemical and Environmental Engineering (Link) at the DICCA of the University of Genova. Within this Ph.D. program, he is currently supervising the research of two Ph.D. students.

Since september 2012 Marco is member of the Department Board of the DICCA of the University of Genova. On appointment of the Director, he is member of the Department Research Commission (from december 2018) and Cineca IRIS delegate (from february 2019).

From september 2012 Marco is continuously involved in regular teaching activities at the Polytechnic School of the University of Genova, as lecturer of courses on Structural Mechanics, Continuum mechanics and Structural morphology for the degree programs in Naval Architecture, Civil Engineering, Chemical Engineering, Electrical Engineering, Biomedical Engineering.

[1] traduzione a cura del CUN - Consiglio Universitario Nazionale (Link)

A. POSITION, EDUCATION AND HONORS

A.1 Current position

From june 2018 Marco is **Associate Professor** for the Academic Discipline ICAR/08 - Structural Mechanics (Scienza delle Costruzioni[2]) at the University of Genova, Italy[3]. Formerly, from september 2012 to may 2018, Marco has held a permanent position of **Assistant Professor**[4] for the Academic Discipline ICAR/08 - Structural Mechanics at the University of Genova, Italy.

From september 2012 Marco joins the DICCA - Department of Civil, Chemical and Environmental Engineering, and is member of the Polytechnic School of the University of Genova.

A.2 Former affiliations

Marco is continuously involved in scientific research activities with different italian institutions since 2002. Before the current affiliation with the University of Genova, he was affiliated with

- the Training and Research Earthquake Engineering Centre (TREEC-CERFIS) of the University of L'Aquila, as holder of Research Grants and Contracts (2012)
- the Department of Structural, Water and Soil Engineering (DISAT) of the University of L'Aquila, as holder of Research Grants and Contracts (2005-2011)
- the Department of Structural and Geotechnical Engineering (DISG) of the University of Rome "La Sapienza", as Ph.D. student (2002-2005)

A.3 Education

Marco graduated from high school with full marks at the Liceo Classico of L'Aquila, Italy (july 1996). Afterwards, Marco awarded

- the five-year **Degree in Civil Engineering** cum laude (July 2002) from the University of L'Aquila, discussing the thesis titled "Dynamic models for the cable-deck interaction in cable-stayed bridges", developed under the supervision of Prof. V. Gattulli.
- the **Ph.D. in Structural Engineering** (May 2006) from the University of Rome "La Sapienza", discussing the thesis titled "Damage identification in taut cables through vibration measurements", developed under the supervision of Prof. F. Vestroni.

Marco passed the Cambridge PET - Preliminary English Test (June 1994), at the UCLES of the English School of L'Aquila.

A.4 Honors and awards

A.4.1 Scientific qualifications

In may 2019 Marco obtained the **National Scientific Qualification** (ASN) to function as Full Professor for the Academic Discipline ICAR/08 - Structural Mechanics. The qualification was granted with unanimous consent of the Examination Committee, in response to the application presented to the first round of the call MIUR-ASN 2019-2020[5].

In march 2017 Marco obtained the **National Scientific Qualification** (ASN) to function as Associate Professor for the Academic Discipline ICAR/08 - Structural Mechanics. The qualification was granted with unanimous consent of the Examination Committee, in response to the application presented to the first round of the call MIUR-ASN 2016-2018[6].

[2] traduzione a cura del CUN - Consiglio Universitario Nazionale (Link)
[3] Professore di seconda fascia, D.R. 2289/2018 (nomina) dell'Università degli studi di Genova
[4] Ricercatore, D.R. 795/2012 (nomina) e D.R. 1968/2016 (conferma) dell'Università degli studi di Genova
[5] D.D. 2175/2018 del Ministero dell'Istruzione, dell'Università e della Ricerca
[6] D.D. 1532/2016 del Ministero dell'Istruzione, dell'Università e della Ricerca

A.4.2 Competitive competitions

Marco participated in several competitive competitions for permanent professor positions, temporary grants or contracts for research programs, as well as for the assignment of fellowships for attending at advanced courses and international conferences. In particular he came out

- winner of a permanent position of **Associate Professor** for the Academic Discipline Icar/08 - Structural Mechanics (april 2018) at the Dicca - Department of Civil, Chemical and Environmental Engineering of the University of Genova, from a competition based on qualifications.
- winner of a permanent position of **Assistant Professor** for the Academic Discipline Icar/08 - Structural Mechanics (april 2012, for the II session 2010) at the Engineering Faculty of the University of Genova, from a competition based on qualifications and oral examination.
- winner of a post-doctoral **one-year Research Grant** (2012/13) for the project "Model formulation and dynamic response analysis of damaged and undamaged structures", at the Cerfis of the University of L'Aquila, from a competition based on qualifications and oral examination.
- winner of a post-doctoral **three-year Research Grant** (2007/08, 2008/09 and 2009/10) for the project "Advanced methods in structural identification for the structural health monitoring and the design of vibration mitigation systems", at the Disat of the University of L'Aquila, from a competition based on qualifications and oral examination.
- winner of a post-doctoral **two-year Research Grant** (2005/06 and 2006/07) for the project "Numerical and experimental methods and procedures for the identification of undamaged and damaged structures", at the Disat of the University of L'Aquila, from a competition based on qualifications and oral examination.
- winner of a **three-year Scholarship** for attending the XVIII cycle (2002-2005) of the PhD course in Structural Engineering, at the Disg of the University of Rome "La Sapienza", from a competition based on qualifications, written and oral examination.
- winner of **4 Marie Curie Fellowships** for the participation to events of the FP6 Marie Curie Action Project Sicon: Stability, Identification and COntrol in Nonlinear structural dynamics
  - Sicon TC3, training course on "Experimental dynamics, model identification and damage detection", held in Rome (june 2008)
  - Sicon TC4, training course on "Advanced nonlinear dynamics and chaotic dynamical systems", held in Lyon (april 2009)
  - Sicon TC5, training course on "Vibration testing, identification of linear and nonlinear systems", held in Liege (july 2009)
  - Sicon CF, international conference on "Nonlinear dynamics, stability, identification and control of systems and structures", held in Rome (september 2009).

A.4.3 Awards

Marco was awarded with a prize for the scientific production related to his research activities

- Iascm Takuji Kobori Prize assigned by the Iascm - International Association for Structural Control and Monitoring for the best paper published during the year 2014 in the journal Structural Control and Health Monitoring [20]

A.5 Memberships

A.5.1 Scientific journals

Since 2014 Marco collaborates with some international scientific journals, mainly focused on the topics of theoretical and applied mechanics

- from october 2014 as **Assistant Editor** of the journal Meccanica (Springer, ISSN: 0025-6455), official journal of the Aimeta - Italian Association of Theoretical and Applied Mechanics

- from june 2015 as member of the **Editorial Board** of the journal SpringerPlus (Springer, ISSN: 2193-1801)
- from september 2015 as member of the **Editorial Board** of the journal Coupled Systems Mechanics (TechnoPress, ISSN: 2234-2192)
- from june 2017 as member of the **Editorial Board** (for the topics Physics and Applied Physics) of the journal 4Open (EDP Sciences, ISSN: 2557-0250)
- from march 2018 as member of the **Editorial Board** of the journal Shock and Vibration (Hindawi, ISSN: 1875-9203)

A.5.2 Scientific commettees

Marco has been member of the scientific committee of some international scientific congresses of international, on the topics of smart materials and structures

- Ancrisst2019 - 14th International Workshop on Advanced Smart Materials and Smart Structures Technology, held in Rome (july 2019)

A.5.3 Committees

From the XXXIII cycle (february 2017) Marco is member of the **Teacher Committee** for the Ph.D. program in Civil, Chemical and Environmental Engineering (Link), offered by the DICCA of the University of Genova. Within the same Ph.D. program, from the XXIX cycle (academic year 2013-2014), Marco is also member of the Curriculum Committee in Structural and Geotechnical Engineering, Mechanics ad Materials.

A.5.4 Registers and professional qualifications

In september 2014 Marco passed the international selection to become **Qualified Expert** of the italian Ministry of Education, University and Research (MIUR) for the Academic Disciplines Icar/08 - Structural Mechanics and Icar/08 - Structural Engineering[7]. The qualification grants the inclusion in REPRISE - Register of Expert Peer-Reviewers for Italian Scientific Evaluation.

In 2002 Marco passed the exam (with marks 120/120) for **Professional Engineer Qualification** at the University of L'Aquila. From march 2003 to march 2017 he has been member of the Italian Association of Professional Engineers, for the sectors Civil and Environmental Engineering, Industrial Engineering and Information Engineering.

A.6 Other affiliations

Marco is associated with **research centres and groups**, working on different aspects of structural mechanics, wind engineering and communication and information technology

- Center of Excellence Dews - Design Methodologies for Embedded controllers, Wireless interconnect and System-on-chip, at the University of L'Aquila, Italy
- Research Group WinDyn - Wind Engineering and Structural Dynamics Research Group of the University of Genova, Italy.

and is affiliated to italian and international **scientific societies** and **associations**

- EuroMech - European Mechanics Society
- Eacs - European Association for the Control of Structures
- Aimeta - Italian Association of Theoretical and Applied Mechanics
- Sisco - Società Italiana di Scienza delle Costruzioni
- Aniv - Italian Association for Wind Engineering
- Gades - Aimeta Group of Dynamics and Stability

[7] D.D. 79/2010/Ric del Ministero dell'Istruzione, dell'Università e della Ricerca

B. SCIENTIFIC RESEARCH ACTIVITY

B.1 Principal research interests

Marco develops his principal research activities in the field of Structural Mechanics. The research involves (i) theoretical aspects related to the formulation of analytical or numerical models, (ii) methodological issues targeted at the development of analytical techniques for the solution of direct and inverse structural problems, and (iii) applied matters concerning civil and industrial engineering, including experimental tests on light prototypes or full-scale structures. The research is mainly focused on the following topics

- dynamics and stability of flexible structures
- mechanics of periodic materials
- dynamic identification of physical, modal and damage parameters
- structural monitoring and vibration control
- earthquake engineering and naval architecture

Within these topics, the principal research interests regard the following issues

- ◦ spectral properties and nonlinear dynamics of cable-stayed structures
- ◦ static and dynamic behaviour of suspended cables
- ◦ dynamics and aeroelastic stability of multi-body section models
- ◦ propagation of elastic waves in beam lattice materials
- ◦ transport of mechanical energy in microstructured materials
- ◦ spectral sensitivity, design and optimization of acoustic metamaterials
- ◦ perturbation methods for multiparametric sensitivity analyses
- ◦ dynamic identification of damage in suspended cables
- ◦ structural identification and experimental modal analysis
- ◦ passive and semi-active control of suspended cables and beam frameworks
- ◦ seismic response and health assessment of existing structures
- ◦ protection and structural monitoring of monumental and strategic buildings
- ◦ linear and nonlinear dynamics of sailing boats

and the main findings of these research activities are summarized in section **??**.

B.2 Scientific publications

Marco authored more than **130 scientific publications**, developed either autonomously or in collaboration, with more than 50 different co-authors. They include

• articles published in international journal	35
• articles published in italian journal	4
• book chapters or monographies	7
• papers included in international congress proceedings	49
• papers included in italian congress proceedings	30
• research reports	7

The total impact of this scientific production on the international literature can be synthetically evaluated by the following bibliometric indexes

• **h-index**:	**17** (Scopus)	**15** (ISI Web of Science)	**19** (Google Scholar)
• **citations**:	**881** (Scopus)	**657** (ISI Web of Science)	**1189** (Google Scholar)

B.3 Research projects, experiences and collaborations

The scientific activity includes the participation in several research projects, the supervision of young researchers, some work experiences abroad, different post-doctoral temporary contracts for research collaborations and experimental activities in many laboratories and sites.

B.3.1 Research projects

Marco participated in several research projects, as leader or member of Research Units (RU) in the framework of scientific programs funded by italian and international institutions.

In particular, Marco has been **Principal Investigator** or **Coordinator** of research projects funded by the University of Genova, as well as **Recipient** of funds for individual research programs financed by the italian Ministry of Education, University and Research

- University of Genova FRA 2015, 2016, 2017, individual annual grants (total 9 000 euros), assigned by the Dicca on the base of bibliometric criteria
- University of Genova PRA 2013, annual grant (6 000 euros) assigned by the Dicca for the project titled "Stability and control of the dynamic response of flexible structures"
- Miur-Ffabr 2017, individual annual grant (total 3 000 euros) assigned by the Miur on the base of bibliometric criteria

whereas, as **Associate Investigator**, he participated in a Research Unit (RU) for the programs

- Miur-Prin 2015, for the project titled "Multi-scale mechanical models for the design and optimization of micro-structured smart materials and metamaterials" (Principal Investigator Prof. A. Corigliano, funded with 478 500 euros for 36 months), RU of the University of Genova (Coordinator Prof. L. Gambarotta, funded with 79 000 euros) Link
- Miur-Prin 2010/11, for the project titled "Dynamics, stability and control of flexible structures" (Principal Investigator Prof. A. Luongo, funded with 349 466 euros for 36 months), RU of the University of Genova (Coordinator Prof. G. Piccardo, funded with 54 000 euros) Link
- Miur-Prin 2006/07, for the project titled "Health assessment and monitoring of civil engineering structures through advanced dynamics methods" (Principal Investigator Prof. A.L. Materazzi, funded with 126 800 euros for 24 months), RU of the University of University of L'Aquila (Coordinator Prof. V. Gattulli, funded with 39 900 euros) Link
- Miur-Prin 2005/06, for the project titled "Modelling and experimental tests of the dynamic behaviour of flexible structures" (Principal Investigator Prof. F. Vestroni, funded with 122 400 euros for 24 months), RU of the University of University of L'Aquila (Coordinator Prof. A. Luongo, funded with 38 000 euros) Link
- Miur-Prin 2004/05, for the project titled "Vinces - Vibrations in civil engineering structures: source of damage and discomfort, diagnostic and safety assessment tool" (Principal Investigator Prof. A.L. Materazzi, funded with 196 800 euros for 24 months), RU of the University of University of L'Aquila (Coordinator Prof. G.C. Beolchini, funded with 32 200 euros) Link
- Dpc-Reluis 2010/13 Task 2.3.2, titled "Development and analysis of new technologies for the seismic retrofit" (funded with 30 000 euros), RU of the University of L'Aquila (Principal Investigator Prof. V. Gattulli) Link
- Dpc-Reluis 2005/08, titled "Technologies for the isolation and control of structures and infrastructures" (funded with 50 000 euros), RU of the University of L'Aquila (Principal Investigator Prof. V. Gattulli) Link
- CarispAQ 2007/11, titled "Mivis: Innovative methods for the structural health monitoring and the seismic protection of the monumental heritage of the L'Aquila province" (funded with 42 000 euros), RU of the University of L'Aquila (Principal Investigator Prof. V. Gattulli)
- Regione Abruzzo POR 2007/08, Action 4, titled "ReCOTeSSC: Networks for the knowledge and the technical/scientific guidance for the development of competitiveness" (funded with 10 000 euros), RU of the University of L'Aquila (Principal Investigator Prof. A. Luongo)

- University of Genoa PRA 2012: "Dynamics and stability of flexible structures" (funded with 4 000 euros), RU of the Dicca (Principal Investigator Prof. F. Tubino)
- University of Genoa PRA 2014: "Simplified models for the dynamic analysis of structures" (funded with 6 200 euros), RU of the Dicca (Principal Investigator Prof. F. Tubino)

B.3.2 Scientific supervision

Within the Ph.D. program in Civil, Chemical and Environmental Engineering (Cod. DOT1311880, Link), offered by the DICCA of the University of Genova, Marco supervises the scientific research of students of the Curriculum in Structural and Geotechnical Engineering, Mechanics ad Materials

- Francesca Vadalà (XXXII cycle), for her theoretical and applied research concerning the mechanical aspects of the elastic waves propagating in periodic materials and acoustic metamaterials.
- Daniele Sivori (XXXIII cycle), for his applied research concerning the methodological aspects of the seismic assessment for masonry structures, based on inverse modal solutions.

B.3.3 Experiences abroad

During the XVIII cycle of the Ph.D. Course in Structural Engineering (2002-2005, University of Rome "La Sapienza") Marco has acquired valuable research experiences abroad

- as **Research Fellow** (November-December 2003) at the *Earthquake Engineering Research Centre* of the University of Bristol (England), under the supervision of Prof. J.H.G. Macdonald and Prof. C.A. Taylor. The research activities dealt with the nonlinear phenomena featuring the cable-beam interactions in cable-stayed structures, analyzed through the formulation of numerical models and the interpretation of experimental data, extracted from the dynamic response of a light prototype tested on a shaking table.
- as **Visiting PhD** (April 2005) at the *Structural Engineering Research Laboratory* of the Empa *Laboratories* of Zurich (Switzerland), under the supervision of Dr. G. Feltrin and Dr. A. Bergamini. The research activities dealt with the damage identification in suspended cables, carried out through experimental tests on reduced-scale models of artfully damaged bridge stays, purposely designed to verify the effectiveness of vibration-based damage identification techniques.

B.3.4 Experimental activities

The experimental activities, concerning laboratory tests on both light prototypes and full-scale structures, have been carried out in the facilities of different italian and foreign institutions

- the Laboratory of Linear and Non-linear Dynamics of the Disat at University of L'Aquila
- the Structural Engineering Research Laboratory of the Empa Laboratories of Zurich (CH)
- the Laboratory for Material and Structural Testing of the Disgg at University of Basilicata
- the Laboratory for Structural Engineering of the Dicca at University of Genova

Other experimental activities regard in-situ tests on different engineering structures: the Vittorio Sora cable-stayed bridge (Brescia), the bell tower of the S.Patrizio Church (Rome), the Engineering Faculty of the University of L'Aquila (Monteluco di Roio), the Basilica di S.Maria di Collemaggio (L'Aquila), the through arch footbridge over viale Serra (Milan).

B.3.5 Post-doctoral research

After the conclusion of the PhD course (November 2005), Marco has been continuously involved in post-doctoral collaborations to different research projects, based on fixed-term contracts

- one-year **Research Grant** at the Cerfis of the University of L'Aquila for the collaboration to the project "Model formulation and dynamic response analysis of damaged and undamaged structures" (2012/13)

- three-year **Research Grant** at the DISAT of the University of L'Aquila for the collaboration to the project "Advanced methods in structural identification for the design of health monitoring and vibration mitigation systems" (2007/08, 2008/09 and 2009/10)
- two-year **Research Grant** at the DISAT of the University of L'Aquila for the collaboration to the project "Numerical and experimental methods and procedure for the identification of undamaged and damaged structures" (2005/06, and 2006/07)
- **Research Contract** at the CERFIS of the University of L'Aquila for the collaboration to the project "Theoretical aspects and experimental applications of dynamic identification techniques for damaged and undamaged structures" (2011)
- **Research Contract** at the DISAT of the University of L'Aquila for the collaboration to the project "Cable-beam interactions in cable-stayed bridges" (2002)

B.4 Seminars and lectures

Complementary activities related to scientific training and dissemination of research results include the offer of thematic seminars for university institutions or the holding of lectures in the framework of training schools for doctoral students or young researchers.

B.4.1 Seminars

Marco has held some seminars at important university institutions

- seminar titled "Linear dynamics, nonlinear dynamics and aerodynamic stability of cable-stayed bridges" held at the University G. D'Annunzio of Pescara (november 2018).
- seminar titled "Microstructural models, analytical solutions and numerical optimization of periodic materials" held at the University of Pavia (febbruary 2017).

B.5 Scientific events and peer-reviews

Other research activities include the organization of training courses, conferences and workshops, and the peer-review of manuscripts submitted for publication in scientific journals or in proceedings of international conferences, the expert revision of scientific proposals submitted to funding calls published by national and international agencies.

B.5.1 Thematic minisimposia

Marco is the organizer of minisymposia accepted in the program of international conferences

- "MS 20 - Wave Propagation in Mechanical Systems and Nonlinear Metamaterials" (co-organized with Francesco Romeo and Yuli Starosvetsky), in the framework of the *European Nonlinear Dynamics Conferences* ENOC 2020, Lyon (France) July 2020.
- "MS 35 - Recent advances in the mechanical modelling of architected materials and periodic structures" (co-organized with Andrea Bacigalupo, Nicolas Auffray and Emanuela Bosco), in the framework of the *International Conference on Nonlinear Solid Mechanics* ICoNSoM 2019, Roma (Italy) June 2019.
- "MS 1218 - Stability and Control of Flexible Structures" (co-organized with Ilaria Venanzi), in the framework of the VII *European Congress on Computational Methods in Applied Sciences and Engineering* ECCOMAS 2016, Hersonissos (Creta) June 2016.

B.5.2 Organizing committees

Marco has been member of the Organization Committee for events organized in the framework of the Marie Curie FP6 action project SICON: "Stability, identification and control in nonlinear structural dynamics" (coordinator Prof. A. Luongo)

- Training Course "SICON TC1 - Stability and bifurcations of nonlinear dynamical systems", held in L'Aquila (july 2007)
- Conference "SICON CF - Nonlinear dynamics, stability, identification and control of systems and structures", held in Rome (september 2009)

Marco has been member of the Organization Committee of some national and international conferences on the themes of structural control, helth monitoring and wind engineering

- 6WCSCM - 6th World Conference on Structural Control & Monitoring, held in Barcelona (Spain) in july 2014
- IN-VENTO-2014 - XIII Conference of the Italian Association for Wind Engineering ANIV, held in Genova (Italy) in june 2014

B.5.3 Revision of scientific papers, congress proceedings and research projects

Marco is regularly employed as **peer-reviewer** for the scientific journals, international congresses and research projects submitted for funding calls published by italian institutions

- Scientific journals: (i) *Acta Mechanica*, (ii) *Advances in Mechanical Engineering*, (iii) *Advances in Structural Engineering*, (iv) *Applied Mathematical Modelling*, (v) *Applied Sciences*, (vi) *Archive of Applied Mechanics*, (vii) *ASME J. Computational and Nonlinear Dynamics*, (viii) *ASME J. Vibration and Acoustics*, (ix) *Comm. Nonlinear Science and Numerical Simulation*, (x) *Composite Structures*, (xi) *Computers and Structures*, (xii) *Coupled Systems Mechanics, An Int. J.* (xiii) *Earthquake Engineering and Engineering Vibration*, (xiv) *Engineering Review*, (xv) *Engineering Structures*, (xvi) *European Journal of Mechanics / A Solids*, (xvii) *Int. J. Architectural Heritage*, (xviii) *Int. J. Mechanical Sciences*, (xix) *Int. J. Non-Linear Mechanics*, (xx) *Int. J. Structural Stability and Dynamics*, (xxi) *Int. J. Solids and Structures*, (xxii) *J. Bridge Engineering*, (xxiii) *J. Engineering Mathematics*, (xxiv) *J. Franklin Institute*, (xxv) *J. Low Frequency Noise Vibration and Active Control*, (xxvi) *J. Marine Science and Engineering*, (xxvii) *J. Optimization Theory and Applications*, (xxviii) *J. Sandwich Structures and Materials*, (xxix) *J. Sound and Vibration*, (xxx) *J. Vibration and Control*, (xxxi) *J. Wind Engineering & Industrial Aerodynamics*, (xxxii) *KSCE Journal of Civil Engineering*, (xxxiii) *Materials*, (xxxiv) *Mathematical Problems in Engineering*, (xxxv) *Mathematical Biosciences and Engineering*, (xxxvi) *Measurement*, (xxxvii) *Meccanica*, (xxxviii) *Mechanical Systems and Signal Processing*, (xxxix) *Nonlinear Dynamics*, (xl) *Scientific World Journal*, (xli) *Sensors*, (xlii) *Shock and Vibration*, (xliii) *Structural Engineering and Mechanics*, (xliv) *The Open Civil Engineering Journal*.
- International conferences: (i) RASD 2013 - 11th *Int. Conf. on Recent Advances in Structural Dynamics*, (ii) 6WCSCM 2014 - 6th *World Conf. on Structural Control & Monitoring*, (iii) IN-VENTO-2014 - XIII *Conf. of the Italian Association for Wind Engineering ANIV*, (iv) IEEE EESMS 2014 - *Workshop on Environmental, Energy, and Structural Monitoring Systems*, (v) PCM2016 - *Global Conf. on Polymer and Composite Materials*, (vi) CMSE2016 - 5th *Int. Conf. on Materials Science and Engineering*, (vii) EURODYN 2017, the 10th *Int. Conf. on Structural Dynamics*, (viii) 2018 IEEE - *Int. Conf. on Environmental Engineering*, (ix) ICPMS 2018 - *Int. Conf. on Physics, Mathematics and Statistics*, (x) CSAE 2018 - *2nd Int. Conf. on Computer Science and Application Engineering*, (xi) NODYCON 2019 - *First International Nonlinear Dynamics Conference*.
- Research projects: (i) MIUR-FIRB 2013, (ii) MIUR-SIR 2014.

- Other research projects: (i) Università degli Studi di Firenze 'Giovani Ricercatori Protagonisti' 2018, (ii) CONICYT - Chilean National Commission for Scientific and Technological Research '2018 FONDECYT Initiation into Research', (iii) Regione Emilia Romagna Por Fesr 2014-2020 Asse 1, Azione 1.2.2 - Contributi per raggruppamenti di laboratori di ricerca.

B.6 Description of the research activities

A brief description of the research activities is presented in the following. For each scientific topic of interest, the main achievements are summarized, and the future developments outlined.

B.6.1 Dynamic behaviour of suspended and cable-stayed structures

With regard to the dynamic behaviour of suspended and cable-stayed structures, the research is mainly focused on the modal interactions which may strongly characterize the linear and nonlinear coupling between global and local modes, dominated by the beam and cable dynamics, respectively.

- Within the linear field, the research mainly regards the modal coupling phenomena that can characterize global and local modes with resonant frequencies. Starting from the modal solution of synthetic models, obtained in an exact analytical fashion for continuous models [13, 33, 86, 129] or in an asymptotically approximate form for finite-dimensional lagrangian models [21, 40, 80], an original mechanical interpretation has been proposed for these interaction phenomena, by virtue of the hybridization process of the resonant modes. An analytical, though asymptotically approximate, expression has been obtained for the internal resonance conditions (1:1) responsible for the phenomenon, whose origin is attributed to the veering between two or more loci of close frequencies, which can occur in some regions of the parameter space. A new energy-based localization factor has been specifically proposed to synthetically describe the rapid evolution of the hybridization phenomenon in the mechanical parameter space [33]. For lagrangian models with a generic finite number of configurational degrees-of-freedom, the localization factor has been conveniently approximated through perturbation techniques, which allow to neglect – in an asymptotically consistent way – the degrees-of-freedom external to the localization zone [21]. In the framework of an international collaboration with a research team from the University of Porto (Portugal), which has allowed the refinement and updating of finite element models based on experimental modal analysis [39, 89], the hybridization of several modes with resonant frequencies has been effectively identified as one of the most probable source of the high-amplitude local vibrations frequently observed in a long span cable-stayed bridge [31, 85, 120, 122].

- Within the nonlinear field, the research employs synthetic parametric models, prevalently reduced to the only few (typically two or three) significant modal degrees-of-freedom. Since the reduced models present complex cubic and quadratic coupling in the amplitudes of global and local modes, their forced response exhibits a rich scenario of multimodal interactions and dynamic bifurcations [35, 87, 88, 119, 129]. In particular, in the case of super-harmonic resonance (1:2) between a global and a local frequency, a new mechanism of cable excitation has been identified, different from the well-known mechanism of parametric excitation that rises up in sub-harmonic resonance conditions (2:1). The novel mechanism determines a continuous transfer of mechanical energy from the low-frequency oscillations of a global mode to the high-frequency oscillations of a local mode. Evidence of this phenomenon has been confirmed by both numerical solutions of finite element models, and laboratory tests conducted on experimental light models, realized at the Earthquake Engineering Research Centre, University of Bristol [34]. The classic mechanism of autoparametric excitation between internally resonant global and local modes has been also recognized in the nonlinear planar model of a nonlinear cable suspended between the free ends of two vertical cantilevers [5, 55, 57, 96]. A lagrangian multi-body section model, based on a kinematically exact formulation, has been instead used to analyze a similar nonlinear phenomenon that can occur in cable-stayed or suspended bridges, when the flexural and/or torsional oscillations of the deck parametrically excite the transversal oscillations of one or more cables (stays or hangers). Leveraging the perturbation solution of the linear modal problem [23], an analytical expression has been obtained to asymptotically assess the parametric conditions of multiple internal resonance (2:1:1) that can favour the onset of dynamic bifurcations governed by the quadratic terms of modal coupling (period doubling). Therefore, using the Multiple Scale Method for the asymptotic solution of the nonlinear equations of motion, analytical expressions have been obtained for the amplitude of the bifurcated stable solutions. As major result for design purposes, the critical oscillation amplitudes of the deck, which trigger the autoparametric excitation of the cables, have been expressed as explicit function of the structural parameters [17, 40, 106].

B.6.2 Static and dynamic behaviour of suspended cables

The static and dynamic response of suspended cables has been primarily studied in relation to the mechanical effects caused by the possible presence of damage and thermal variations.

- With regard to DAMAGE, the research moves from the formulation of an original continuous model, kinematically nonlinear, describing the static and dynamic behaviour of damaged cables, even in the absence of pretension [32]. The damage has been described as a diffused reduction of the longitudinal elastic stiffness, resulting in a non-negligible loss of the transversal geometric stiffness. Closed-form solutions have been obtained for the static problem, as well as for the eigenproblem associated to the linearized dynamic model. Therefore, it has been possible to describe the effects of damage on (i) the static equilibrium configuration and (ii) the spectral properties of the cable, taking into account the longitudinal elasticity. The main recognizable effect is the systematic reduction of all the natural frequencies. The frequency reduction can be attributed to the concurrence of a curvature increment in the static reference configuration (*static effect*) and a geometric stiffness decrement due to a reduction of longitudinal tension (*geometric effect*). The static effect acts on the symmetric modes only. Remarkably, the damage effect of the cable frequency can synthetically be described as an equivalent value of the Irvine parameter. The equivalence depends only on the damage severity (intensity and extent), but is independent of the damage position. The analytical results have been also confirmed by the formulation and solution of finite element numerical models. The damage effects have also been described with respect to the nonlinear response in the free oscillation regime [131]. In this regard, the damage can exalt the hardening or softening behavior of the frequency response functions, depending on the different values of the equivalent Irvine parameter.

- With regard to the THERMAL VARIATIONS, the research moves from the formulation of a continuous model, kinematically nonlinear, to describe the static and dynamic behaviour of elastic suspended cables undergoing a uniform temperature change [24, 124]. Exact and asymptotically approximate solutions have been carried out for the nonlinear static problem, independently of the inclination angle of the chord between the cable supports. Parametric analyses on the most significant static and kinematic variables have demonstrated that the approximate solution allows a sufficiently-accurate description of the thermal effects. Thus the approximate solution has been suitably employed as reference configuration to simplify the nonlinear dynamic model. The linearized eigenproblem associated to the small-amplitude oscillations has been solved for parabolic and cubic cables in an exact and approximate fashion, respectively. In strict analogy with the mechanical effects caused by damage, the thermal variations have been recognized to determine a static and a geometric effects. As significant difference, the geometric effect due to thermal variations produces a systematic increment or reduction of all the frequencies, depending on the sign of the temperature change. The static effect can stiffen or soften only the symmetric modes of the cable, and may also prevail over the competing geometric effect over a limited value-range of the cable Irvine parameter. The analytical solutions have been confirmed by numerical analyses on finite element models.

B.6.3 Aeroelastic stability of suspended and cable-stayed bridges

With regard to the aeroelastic stability analyses, the research concerns the formulation of discrete multi-body models, with a few degrees-of-freedom, able to synthetically describe the sectional dynamic response of suspended bridges to a stationary wind flow acting laterally on the deck cross-section, characterized by double geometric symmetry [19, 40, 69]. With respect to state-of-the-art on the topic, significant advances are related to the enrichment of the descriptive possibilities of the proposed models, which can simultaneously capture both the internal structural interactions among the deck and a pair of hanger cables (caused by the geometric stiffness), and the aerodynamic coupling between the vertical and torsion components of the deck motion (due to a stationary wind flow acting along the horizontal symmetry axis). As common for cable structures, the free dynamics is strongly characterized by global modes, dominated by the two components of the deck motion, and local modes, dominated by the cable transversal motion. The employment of a multi-parameter perturbation method [23], applied to the solution of the classic modal problem when internal resonance conditions among global and local modes occur, allow an asymptotically consistent reduction of the model dimensions. The local stability analysis in the resonant regions highlights a complex bifurcation scenario, which in the parameter space exhibits different instability boundaries, interacting to each other. In particular, the analysis of the critical wind velocity, responsible for the galloping phenomenon, reveals that resonant or nearly-resonant light cables may improve the deck stability. Moreover, the introduction of auxiliary viscous dampers, acting on the cable-deck differential velocity and typically designed to passively control the cable vibration (in service condition), may have a beneficial effect in the prevention of the aeroelastic instability (limit state condition), through a significant increment of the critical wind velocity [107].

B.6.4 Propagation of elastic waves, spectral optimization and energy transport in materials with periodic microstructure

With regard to the mechanics of periodic materials, the research mainly concerns the propagation of elastic waves and the transport of mechanical energy in different microstructured materials and metamaterials. The microstructure of the periodic cell, typically featured by a composite architecture of rigid rings and deformable ligaments, has been prevalently described by structural formulations based on the elastic coupling between rigid bodies and flexible beams (beam lattices). By virtue of the quasi-static condensation of passive degrees-of-freedom, in which only internal elastic forces may develop, low-dimensional lagrangian models have been formulated in the reduced space of the only active degrees-of-freedom, in which inertial forces may act [9, 14, 61, 102].

- The PROPAGATION OF ELASTIC WAVES has been studied by analyzing the dispersion properties of the harmonic waves propagating in different periodic materials, mainly characterized by chiral or antichiral microstructures of the elementary cell. The dispersion functions defining the spectrum (or band structure) of the tetrachiral and anti-tetrachiral materials have been obtained by stating and solving the eigenproblem resulting by the application of the Floquet-Bloch theory. Exact and/or asymptotically approximate forms have been provided for the eigensolution. Coupling the active degrees-of-freedom with auxiliary tuned oscillators (*resonators*) transforms the periodic material into an acoustic metamaterial, described by an enlarged space of mechanical parameters and characterized by a spectrum enriched by additional dispersion curves. As original contributions: (i) multiparametric perturbation methods have been applied to perform local sensitivity analyses, obtaining analytical, though approximate, descriptions of the dispersion functions as explicit functions of the parameters [14], even in the presence of resonators [9, 58], (ii) nonlinear numerical methods of parametric optimization have been applied to maximize the spectral amplitude of the band gaps occurring in the low-frequency range of the dispersion spectrum [6, 12, 15, 59, 60, 92, 98], (iii) the spectral sensitivity to structural imperfections has been studied to achieve parametric solutions for inverse eigenproblems, targeted to the functional design of periodic materials with assigned harmonic components in the band structure [10, 101], (iv) spectral sensitivity analysis have been performed in the enlarged parameter space including the structural properties of the resonators, to the aim of realizing mechanical filters characterized by stop bands with assigned amplitude and center frequency [9], (v) different mechanical formulations (lagrangian models, high-fidelity solid models, equivalent micropolar homogeneous models) have been compared to cross-check the their accuracy in terms of dispersion properties [7, 54], (vi) the pass and stop bands characterizing the spectrum of particular composite microstructures, even non-centrosymmetric, have been investigated [54, 93, 97], (vii) the effects induced by geometrically nonlinear resonators on the dispersion properties of acoustic metamaterials have been studied [3, 50, 52], (viii) integral laws governing the viscoelastic coupling between the local resonators and the periodic cellular microstructure has been studied to investigate the effect of enhanced constitutive relations on the free and forced response of acoustic metamaterials [47, 90].

- The TRANSPORT OF MECHANICAL ENERGY has been studied by analyzing the waveforms associated with the dispersion functions of periodic materials characterized by a generic beam lattice microstructure. The effects of the wave polarization on the flow and velocity of the mechanical energy transport have been considered. As original contributions (i) a polarization factor of the elastic wave based on energy ratios has been defined [8, 100], in analogy to the localization factors already proposed in the classic modal analysis [33], (ii) a vector quantity has been defined to represent the directional flow of mechanical energy transported by a generic natural motion and, more particularly, by a harmonic elastic wave [8, 56, 100], in analogy to the Umov-Poynting vector commonly used in solid mechanics, (iii) asymptotic approximations of the wave polarization factor and the directional flow of mechanical energy have been formulated by virtue of multiparametric perturbation techniques [91, 94].

B.6.5 Sensitivity analysis of the eigensolution of nearly-resonant systems

With regard to the eigensolution sensitivity analysis of linear or linearized systems, the research focuses on multi-parameter perturbation methods for the asymptotic approximation of the modal properties - eigenvalues and eigenvectors - of Hamiltonian dynamical systems featured by internal resonance or nearly-resonance conditions. Considering that perfectly-resonant systems are typically represented by engineering structures characterized by nominal periodicity (pendulum chains, multi-span beams, bladed disks), or symmetry (horizontal cables, circular arches, cylindrical shafts, spherical shells), the frequency closeness (mistuning) which characterizes instead nearly-resonant systems can be attributed to the introduction of small imperfections (disorders) and/or weak interactions (coupling) among the resonant degrees of freedom. In these cases the modal properties show a high sensitivity to the disorder or coupling parameters, which may lead to linear interaction phenomena as frequency veering and modal hybridization. The method proposed for the eigensolution sensitivity analysis in presence of small parameter modifications requires the formulation and solution of a twofold problem. Known a particular nearly-resonant system (experimental system), the *inverse problem* concerns the identification of an unknown perfectly-resonant, ordered and uncoupled system (ideal system). Therefore, the *direct problem* concerns the employment of the ideal system for the asymptotic, uniformly valid approximation of the eigenproperties of each nearly-resonant system which may born from the application of a generic multi-parameter perturbation (real system), including the experimental system as particular case. The proposed technique has been initially applied to discrete systems with a few degrees-of-freedom, which allow the exact solution of the inverse problem [78, 114]. Afterwards, the method has been generalized for N-dimensional discrete systems with a generic number $n \leq N$ of resonant degrees-of-freedom, in which even the inverse problem requires a perturbation solution technique [23, 71, 108].

B.6.6 Dynamic identification of damage in suspended cables

With regard to the dynamic identification of damage in suspended cables, the research activity leverages the solution of the *direct problem*. Specifically, the modifications induced by damage in the modal properties of the linearized cable model have been selected as reliable damage indicators. The frequency reductions, as can be extracted from the experimental dynamic response, have been used as input data to develop a model-based procedure for the identification of the damage position, intensity and extent [30, 84, 121]. The effectiveness and robustness of the identification procedure have been first successfully tested with pseudo-experimental data, adopting appropriate criteria for selecting the observed variables. Issues related to the uniqueness and sensitivity of the identification solution to the experimental errors have been also discussed. Then two programs of laboratory tests have been conducted on light models of structural cables, artificially damaged. The data collected at the Laboratory of DISAT of L'Aquila (Italy) and the EMPA Laboratories in Zurich (Switzerland) have finally confirmed the practical applicability of the procedure. Recently, the potential reduction of the damage parameter identificability in presence of significant modifications of the cable modal properties due to thermal effects has been also evaluated [73, 110].

B.6.7 Identification of modal and physical parameters of structures

With regard to the identification of modal and physical parameters of structures, the research focuses on the application of output-only identification techniques, mainly working in the frequency domain. The effectiveness and robustness of these techniques have been qualitatively and quantitatively analyzed, with focus to the importance attributable to the excitation measure and in comparison to alternative methods working in the time-domain. The analyses have been referred to a case study, within a joint research program with a research team of the Politecnico di Torino (Italy) [26]. The theoretical studies have been accompanied by intense experimental activities both in the laboratory, on reduced-scale prototypes, both on site, on full scale structures of reinforced concrete and masonry buildings. The experimental activity has been oriented to the formulation, calibration or updating of analytical and numerical models of the dynamic behavior, as well as to the evaluation of the modified or residual mechanical characteristics on the basis of the modal parameter sensitivity to the observed quantities. Specifically, the laboratory tests have been aimed at identifying structural models of a steel frame realized at reduced scale (2:3), excited by environmental vibrations [117]. A program of experimental tests has been conducted in collaboration with a research group of the Politecnico di Bari (Italy). The experimental modal analyses have been targeted at identifying structural models, analyzing the forced response and reducing the inadmissible vibration levels of a reinforced concrete structure [29, 79, 81, 118, 125]. A complementary research line is instead targeted at developing analytical tools for the experimental validation of the actual applicability limits inherent to the simplifying mechanical hypotheses commonly adopted in the structural modeling of existing buildings. The proposed procedures, based on the inversion of the kinematic problems of rigid and deformable structural models, have been verified on a pseudo-experimental and experimental basis, both in a laboratory environment and on site [1, 48]. The evaluation of the actual modal deformability in the identified structural models has been effectively adopted as a useful operational tool, suited to support extensive ambient vibration tests on stocks of strategic buildings, targeted at standardizing automatic procedures for the assessment of the seismic vulnerability at different urban levels [48, 51, 53].

B.6.8 Passive control of cable oscillations

With regard to the passive control of cable oscillations, the research focuses on the mitigation of the dynamic response to external or parametric excitation through the employment of tuned mass dampers or transversal viscous and magneto-rheological devices.

- with respect to the passive control of the aeolian vibrations of a non-resonant suspended cable, the research analyzes the influence of an auxiliary linear oscillator on the aeroelastic response of a flexible cable under the transversal action due to a stationary fluid flow [123]. An original model has been formulated, with a continuous and discrete description of the cable and the oscillator dynamics, respectively. The model is able to capture the linear interaction between the two sub-systems, furnishing the spectral properties of the coupled system. Tuning the mechanical parameters of the auxiliary oscillator to make its frequency resonant to one of the cable frequencies, the system shows a frequency veering phenomenon. The model has been reformulated in an approximated asymptotic way, valid in the neighbourhood of the veering region, for small values of the auxiliary mass. This model has been used to describe the critical manifolds of incipient galloping instability in the parameter space. The explicit dependence of the manifolds from the physical parameters can be used to optimize the passive control effect.

- simultaneously to the employment of tuned mass dampers, an alternative research line explores the possibility of using transverse dampers [82]. A coupled cable-damper model has been formulated to describe both the geometric nonlinearity of cable and the elasto-visco-plasticity of the damper. Different rheological models, with increasing complexity, have been formulated for the damper, with the aim to reproduce, in particular, the behaviour of magneto-rheological devices, suitable for the future implementation of semi-active control techniques.

B.6.9 Semi-active control of frame structures

With regard to the semi-active control of frame structures, the research moves from the analytical modelling of the 3-D seismic response of an asymmetric two-story frame, as part of a national project (Dpc-Reluis), aimed at mitigating the seismic-induced vibrations of buildings and other civil structures. An parametric discrete model, completely flexible, has been initially formulated, and subsequently reduced to a few degrees of freedom through the quasi-static condensation of the passive components of motion [130]. The model has been used (i) in the design phase of a semi-active control strategy, which exploits the remotely electro-controlled properties of a pair of dissipative chevron braces embedding magneto-rheological dampers [46, 83], and (ii) as the initial reference for the identification of the modal and physical characteristics of a large-scale prototype, experimentally tested at the Disgg laboratory at the University of Potenza (Italy). The identification process has been conducted through output-only techniques, by applying ad-hoc procedures for processing the experimental dynamic response in the frequency domain [117, 128]. Excellent results were obtained for both the identification of a complete modal model, and the updating of the reduced physical model, conducted by exploiting the sensitivity of the spectral properties to small variation of the system mass and stiffness. With regard to the semi-active control of the seismic response, the design of the control strategy for the updated model has been based on a H2/LQR technique for defining optimal parameters, while the real-time control of the parameters has been guided by a clipped optimal law [45, 46, 116, 127]. Some key issues for an effective applicability of the semi-active control of the seismic response in civil engineering have been recognized [28, 43, 77]. Among them: (i) the need for an accurate modeling of the interaction between structure and dissipation devices, including model-updating procedures based on experimental data, (ii) the possibilities relying in an improved description of the constitutive laws of magneto-rheological dampers, in both active and passive configuration, (iii) the appropriateness of an integrated design scheme, including the optimal placement and sizing of dampers. About the last issue, different strategies for the design of the mechanical characteristics of elasto-viscous devices, based on simplified structural models and sensitivity analyses, have been proposed [22, 44, 72, 74].

B.6.10 Analysis of the seismic response, safety assessment, seismic protection and integrated structural health monitoring of monumental and strategic buildings

With regard to the seismic engineering and related topics, the research is deeply rooted in the work experience of the Operative Unit of Seismic Engineering of the Disat (Disat-Uois), born soon after the destructive earthquake that struck the city of L'Aquila in April, 2009. In addition to several activities in support of the city and the University of L'Aquila (including visual inspections to assess the safety of public and private buildings, repeated surveys for the detection and estimation of the damage affecting the university buildings, characterization studies of the registered seismic action), phenomenological and numerical analyses have been conducted for the investigation of the seismic performance of historic and modern buildings, including reinforced-concrete and masonry structures [27]. These studies, accompanied by numerous experimental tests for the characterization of the material properties, have allowed the interpretation of the structural mechanisms that featured the seismic performance of lightly-to-heavily damaged structures. For some heavily damaged structures, deeper insights have regarded the assessment of the residual capacity in terms of seismic performance [76, 112, 113, 115, 126] and, for a few strategic buildings, the design of advanced systems of seismic protection bases on passive control strategies [74, 76, 109]. This last aspect has been included among the significant developments of the european research activities related to the structural control in the civil engineering field, from the perspective of the Eacs - European

Association for the Control of Structures [20]. These activities have represented also an important occasion to establish inter-university relations, including a fruitful collaboration with a research team form the University of Catania (Italy) [11, 42]. The experience gained has also contributed to the institution of the Training and Research Earthquake Engineering Centre (Treec-Cerfis) of the University of L'Aquila, whose establishment has allowed the coherent integration of the research activities in a wider multi-disciplinary context. In this respect, a significant result with major applied technological outcomes is the conceptual design and technical development of an advanced system for the structural health monitoring, based on a wireless network of accelerometers [25], which is being successfully used for the remote monitoring the dynamic response of monumental structures [13, 18, 41, 62, 63, 65, 68, 75, 111]. The latter aspect can be located in the rich and consolidated tradition concerned with the employment of structural health monitoring procedures as effective tools for investigating and safeguarding the Italian historical heritage [16]. Once achieved the full operational functionality of the architecture for collecting and transmitting data, the system is currently under further development in the framework of a multi-disciplinary collaboration with the Centre of Excellence Dews (Design methodologies for Embedded controllers, Wireless interconnect and System-on-chip) of the University of L'Aquila. The objective is the development of a hierarchical wireless network of smart nodes, namely multi-sensors equipped with microprocessors, for the decentralization of basic algorithmic operations. The network design is oriented to couple traditional measurement functions with advanced capabilities of real time self-adaptation, self-diagnosis and auto-updating.

B.6.11 Homogenization in micropolar continua of periodic blocky materials

In the framework of the mechanical formulations concerning periodic blocky materials, analytical problems related to the static behavior (deformation under pure shear stress) and the dynamic response (free propagation of elastic waves) have been investigated, by comparing the behavior of lagrangian models with that of micropolar continua featured by equivalent elastic properties [4, 99]. Specifically, an improved continualization technique - based on the use of pseudo-differential operators expanded in Maclaurin series - has been successfully used for the approximation of the dispersion spectra that characterize the elastic wave propagation in one-dimensional chains of rigid stacked materials with elastic joints [4]. The proposed technique is energetically consistent and leads to the definition of homogenized micropolar models, described by continuous variables and characterized by non-local inertia terms, involving the spatial derivatives of the acceleration fields. The approximation obtained is centered at the limit of long wavelengths and is sufficiently accurate even in the presence of a supporting elastic half-space, purposely introduced to allow the opening of spectral band gaps in the ultra-low frequency range. The accuracy can be systematically improved by introducing higher-order terms from the Maclaurin series. The results obtained are particularly significant for the design of phononic filters for very-low frequencies, by-passing the need of introducing strongly massive local resonators.

B.6.12 Identification of global elastic properties and novel auxetic materials

With respect to the static identification of the elastic properties characterizing architectured materials, the theoretical and experimental research activities are focused on periodic materials characterized by honeycomb microstructure, which may exhibit unusual, extreme or customizable mechanical properties. In particular, the studies have analyzed the auxetic directional behavior of planar tetrachiral materials, using analytical, computational and experimental methods [2]. The theoretical predictions about the global elastic properties in the material plane (Young modulus and Poisson ratio) have been successfully validated by performing quasi-static laboratory tests on polymeric samples realized with high-precision 3D printing technologies. The experimental tests required the use of photogrammetric techniques for the graphic rendering of the deformed configurations of the sample, followed by the employment of digital processing methods for the treatment of the rendered images. The entire study is the result of a fruitful collaboration with a research group of the University of Pavia. Taking inspiration from the kinematic behavior of the tetrachiral material, an original two-layered microstructural topology, referred to as *bi-tetrachiral* material, has been first conceptually conceived and then mechanically modeled. The new topology exploits the reciprocal collaboration between two tetrachiral layers with opposite chirality, kinematically coupled to the boundaries. The bi-tetrachiral material has been verified to outperform the tetrachiral material in terms of global Young modulus and – as major result – has been found to possess a marked auxetic behavior. In particular, the experimental results have shown the effective possibility of obtaining highly negative Poisson ratios, confirmed by analytical and computational verifications. Parametric analyzes have allowed to recognize the strong auxeticity as a peculiar global elastic property of the new layered topology, regardless of the sample size.

B.6.13 Buckling, linear and nonlinear dynamics of sailing boats

With regard to the linear and nonlinear dynamics of sailing boat, the research concerns the original formulation of a synthetic planar model to describe the structural behaviour of hull-mast-sail systems. The minimal structural scheme in the sagittal plane includes a flexible linear cantilever beam, describing the mast, coupled with an inextensible nonlinear cable, representing the foresail supported by the forestay [64, 103]. Considering the periodic pitching motion in the vertical plane, driven by the sea waves, a quasi-static approximation of the wind forces transferred by the cable to the beam tip is adopted, as simplest approximation in steady wind conditions. Since the wind action on the cable (sail) tends to highly compress the beam (mast), a buckling analysis of the linearized static model is performed to assess the critical wind load. Therefore, within the undercritical range, a quadratically-nonlinear one-degree-of-freedom model is obtained through a standard discretization in the reduced base of the fundamental linear mode. A direct and parametric excitation of the cantilever beam are found to participate in the wind-sail-mast interaction, providing a possible mechanical interpretation for the onset of high-amplitude mast oscillations (*mast pumping*). Parametric analyses are carried out to assess the importance of the nonlinearities. Finite element analyses confirm and validate the analytical results.

B.6.14 Complementary research topics

Complementary research topics of interest concern the architecture of computer-aided management systems for the safety assessment and maintenance of structures and infrastructures [36–38].

C. TEACHING AND INSTITUTIONAL RESPONSIBILITIES

From 2002 Marco has been continuously involved in teaching activities within the Academic Discipline ICAR/08 - Structural Mechanics, first as Teaching Assistant at the University of L'Aquila, Italy (2002-2012) and, from september 2012, as Assistant Professor at the University of Genova.

C.1 Teaching activity

C.1.1 Degree courses

From the academic year 2012/13 Marco is involved in regular teaching activities at the Polytechnic School of the University of Genova, as **lecturer** of courses

- Structural Mechanics (SSD ICAR/08), for the 2nd year of the three-year degree course in Naval Architecture (a.y. from 2012/13 to 2018/19)
- Structural Mechanics (SSD ICAR/08), for the 3rd year of the three-year degree course in Chemical Engineering (a.y. from 2012/13 to 2015/16)
- Solids Mechanics (SSD ICAR/08), for the 2nd year of the three-year degree course in Electrical Engineering (a.y. from 2012/13 to 2018/19)
- Continuum Mechanics (SSD ICAR/08), for the 1st year of the two-year Master degree course in Biomedical Engineering (a.y. 2017/18)
- Structural Morfology (SSD ICAR/08), for the 1st year of the two-year Master degree courses in Architecture, Architectural Engineering and Civil Engineering (a.y. from 2017/18 to 2018/19)
- Structural Mechanics (SSD ICAR/08) for the 1st year of the two-year Master degree courses in Engineering for building retrofitting (a.y. from 2018/19)

C.1.2 Ph.D. programs

From 2014 Marco participates in the teaching activities for the Ph.D. program in Civil, Chemical and Environmental Engineering (Link) at the Dicca of the University of Genova, offering the short courses (20-hours, in collaboration with Prof. G. Piccardo)

- Introduction to Perturbation methods (2014)
- Elements of Perturbation methods (2015)
- Perturbation methods II (2016, 2017, 2018)

for the Curriculum in Structural and Geotechnical Engineering, Mechanics ad Materials, and the Curriculum in Fluid Dynamics and Environmental Engineering.

C.2 Teaching assistance

From 2002 to 2012 Marco gave teaching assistance, including complementary lectures on theoretical and practical arguments, monographic seminars and membership of the examination committee, for courses of the Engineering Faculty of the University of L'Aquila

- Structural Mechanics (SSD ICAR/08), for the degree course in Environmental Engineering (a.y. from 2002/03 to 2011/12, responsible Prof. V. Gattulli)
- Computational Mechanics (SSD ICAR/08), for the degree courses in Civil Engineering and Environmental Engineering (a.y. from 2002/03 to 2010/11, responsible Prof. V. Gattulli)
- Metallic Structures (SSD ICAR/09), for the degree course in Civil Engineering (a.y. 2006/07, responsible Prof. G. Valente).

Marco was awarded the qualification of **Cultore della materia** for the Academic Discipline ICAR/08 - Structural Mechanics at the Engineering Faculty the University of L'Aquila (2005-2011).

C.3 Examination Committees

C.3.1 Doctoral Dissertations

Marco has served as member of the **Doctoral Dissertation Committee** for the oral examination of candidates defending their Ph.D. theses for

- the XXXI cycle of the Ph.D. program in Structural and Geotechnical Engineering, offered by Sapienza Università di Roma (february 2019).
- the XXX cycle of the Ph.D. program in Mathematics and Modeling, offered by the University of L'Aquila (april 2018).
- the XXX cycle of the Ph.D. program in Civil, Construction-Architectural and Environmental Engineering, offered by the University of L'Aquila (may 2018).

C.3.2 Degree Dissertations

Marco has repeatedly served as member of the **Degree Dissertation Committee** for the oral examination of candidates defending their Degree theses for

- the degree course in Naval Architecture by the University of Genova (a.y. 2012/13).
- the degree course in Chemical Engineering by the University of Genova (a.y. 2013/14, 2015/16).

C.3.3 Other qualifications

In 2014 Marco has served as aggregate member for the **Examination Committee** for Professional Engineer Qualification at the University of Genova.

C.4 Supervision of degree theses

Marco has supervises some **Degree theses** for the degree courses in Chemical Engineering at the Polytechnic School of the University of Genova [133, 133].

Marco has co-supervises some **Degree theses** for the degree courses in Civil Engineering at the Engineering Faculty of the University of L'Aquila [134]-[137].

D. ACADEMIC ROLES OF RESPONSIBILITY AND SUPPORT

Since the conclusion of the Ph.D. Course, Marco is continuously involved in institutional activities, documented by the assumption of responsible roles in Academic Bodies and Work Groups.

D.1 Department bodies

D.1.1 Department board

From september 2012 Marco is member of the **Department Board** of the DICCA - Department of Civil, Chemical and Environmental Engineering of the University of Genova.

From 2006 to 2010 Marco has been member of the **Department Board** of the of DISAT - Department of Structural, Water and Soil Engineering of the University of L'Aquila (2006-2010), as elected representative of the PhD students and post-Doctoral researchers.

D.1.2 Department commissions and responsibilities

On appointment of the Director of the DICCA - Department of Civil, Chemical and Environmental Engineering, Marco is member of the Department Research Commission (from december 2018) and Cineca IRIS delegate (from february 2019).

D.2 Teaching bodies

D.2.1 Degree courses

Marco has been member of some **Study Course Boards** at the University of Genova for

- the degree course in Naval Architecture (a.y 2012/13 and from 2014/15 to 2017/18)
- the degree course in Electric Engineering (a.a 2012/13)
- the degree course in Chemical Engineering (a.a 2013/14)

D.2.2 Work groups

Marco has been member of the Work Group responsible of the structural project of seismic retrofitting for the Engineering Faculty of the University of L'Aquila, heavy damaged by the seismic events of April 2009, in the framework of the no-profit activities of the ONLUS "Comitato Rotary per l'Università dell'Aquila". Under the supervision of the group coordinator, Prof. V. Gattulli, Marco was appointed for the "Formulation of models for the seismic performance evaluation of the Edifice A of the Engineering Faculty".

Marco has been fixed-term contractor for the "Support to the activities of the Operative Unit of Seismic Engineering (UOIS) of the University of L'Aquila", purposely established to respond to the post-seismic emergency after the 2009 L'Aquila earthquake.

LIST OF PUBLICATIONS

International journals

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