DICAM
DEPARTMENT OF CIVIL, CHEMICAL, ENVIRONMENTAL AND MATERIALS ENGINEERING

RESEARCH PROJECTS AND ACTIVITIES
2015

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DICAM OVERVIEW

It is with great pleasure that I welcome this publication of the Department of Civil, Chemical, Environmental and Materials Engineering (DICAM). The present volume is aimed to present a concise and comprehensive overview of the DICAM research projects and scientific activities, carried out by its numerous research groups.

Obviously, this publication provides only a still image of the ongoing activities, thus requiring continuous update, thanks to the constant evolution and liveliness already shown since the birth of the Department. To such purposes, the Department has also developed a dynamic web site, which represents a precious source of information and a valuable tool to promote scientific exchange and technological transfer.

What emerges from this picture is a rich and articulated portrait of the varied skills and potentials of the Department, the first one of the University of Bologna to succeed in the recent strategic plan of resources and people aggregation of different but interrelated engineering branches.

DICAM currently comprises more than 150 Researchers and Professors, including a large number of PhD students and Research fellows. It incorporates researchers and collaborators from different former Departments of the School of Engineering and Architecture of the University of Bologna.

Since 2013, the Department also manages the education activities. Together with the traditional BS and MS Courses taught in Italian (in the areas of Civil Engineering, Chemical Engineering and Environmental Engineering, with a total of more than 1500 students enrolled), the Department also manages the following two-year international master programmes completely taught in English: Chemical and Process Engineering (curriculum “Sustainable Technologies and Biotechnologies for Energy and Materials”), Environmental Engineering (curriculum “Earth Resources Engineering”), Civil Engineering, and, in collaboration with the Department of Architecture, the international curriculum “Rehabilitation of Historic Buildings” within the master programme in Engineering of Building Processes and Systems, held in Ravenna Campus. Thanks to agreements with top Universities in the world (including Columbia University, NY), students can earn two Master degrees in two years, by spending the second year abroad.

The collaboration with companies operating in the Ravenna area and with international research institutes has lead to the development of a new field of specialization and to the implementation of a new curriculum in “Offshore Engineering” to be offered as an option for students enrolled in our international Master Degree Programmes.

Finally, the Department is involved in the following postgraduate 1-year professional master programs: Timber Constructions (Assolegno) and Design of Oil & Gas Plants (ENI). All courses are given in English.
The Department has also a very active PhD program in Civil, Chemical, Environmental and Materials Engineering, with more than 80 students enrolled. The PhD program encompasses the following internal curricula: 1) Infrastructure, Resource and Land Engineering; 2) Structural and Geotechnical Engineering; 3) Chemical and Process Engineering; 4) Materials Engineering and Industrial Biotechnologies.

The high quality, interdisciplinary nature and collaborative work of the research groups enable the Department to provide, worldwide, an effective answer to the demands of today’s modern society and of professional world. This was possible as a result of clear leadership with international individual recognition at the management level but also extending to many of the individual members who progressively assume greater visibility in the international arena.

The Department faces many challenges for its future. Continuing its quest for excellence, with real impact in science and technology, is a clear goal. This goal relies on people and this is the most important asset of DICAM. Now and for the future our mission is to make the Department an ever more challenging place to be for young researchers. For all of them, my warmest thanks for the privilege of leading an enthusiastic team.

Francesco Ubertini  
Department Head
FOREWORD

The Department of Civil, Chemical, Environmental and Materials Engineering (DICAM) is the result of a large aggregation of research skills and laboratory facilities of diverse but interrelated engineering branches traditionally developed at the University of Bologna. The department integrates the scientific expertise of various research groups, such as Structural, Transport, Hydraulic, Survey and Territory Engineering, Applied Chemistry and Materials Science, Chemical, Mining, Petroleum and Environmental Engineering.

The main objective of the aggregation was bringing together, within a large scientific and administrative organization, many of the multifaceted activities of the School of Engineering and Architecture at the University of Bologna. The mission of the Department is to create and develop advanced research in the areas of civil, chemical, environmental and materials engineering, starting from evaluation, design, construction and service of manmade structures and infrastructures (including industrial production facilities), through the study and characterization of the constituent materials, up to the environmental analysis and impact assessment of the footprint on the territory and the environment.

More than 320 people currently team up to the Department research activities: 105 academic staff, 45 technical, administrative and librarian staff and 174 Ph.D. students, research assistants and research fellows.

The Department is based in the two main locations of the School of Engineering and Architecture of the University of Bologna, the historical building of downtown Bologna and the new building in the strategic urban development of Via Terracini, in the close outskirt of the historical downtown, which houses the largest part of the Laboratory facilities and many modern offices for Researchers and Professors. However, staff’s activity also takes place at the satellite University of Bologna Campuses of Cesena and Ravenna.

As far as Research activities are concerned, the Department encompasses 14 specialized laboratories, which represent a large propulsive element to the research in all the specific disciplines, as well as an essential element for the teaching activities. The following are the Labs facilities currently operating in the Department: Laboratory of Bioreactors, Photocatalytic Processes and Applied Fluid-dynamics (LABIOFF), Laboratory of Computational Mechanics (LAMC), Laboratory of Environmental Biotechnology and Biorefineries (LABIOTEC), Laboratory of Geoengineering and Natural Resources (LAGIRN), Laboratory of Hydraulic Engineering (LIDR), Laboratory of Industrial Safety and Environmental Sustainability (LISES), Laboratory of Land Surveying and Geomatics (LARIG), Laboratory of Macromolecular Synthesis and Materials Characterization.
(LAMAC), Laboratory of Materials Science and Technology (LASTM), Laboratory of Membrane Processes, Bioseparations and Diffusion in Polymers (LABMEM), Laboratory of Road Constructions (LAS), Laboratory of Structural and Geotechnical Engineering (LISG), Laboratory of Transport Network (LART).

The aim of collecting and making available all useful info about the life of the Department has been fundamental since its origin. To such purposes, an Editorial Board was established, originally aimed to plan and develop a modern website (www.dicam.unibo.it), which has now become more than just a source of constantly updated information, but also a remarkable working tool for all the Department staff, fostering its institutional relationships with the external world. In the website section illustrating the research projects and scientific activities, information and references have been progressively and constantly gathered, accounting for the scientific liveliness of the various research groups within the department. Therefore, it was deemed appreciable and useful to put together all these materials in this booklet, which represents a concise but comprehensive compendium of the Department scientific activities.

All the research topics are presented in a 2-pages format which includes title and keywords, people of the research group, contact person, a short summary with figures and a list of the key publications. Each topic has been then grouped into homogeneous categories, which have been in turn classified under more general research areas, resulting in an overall picture, organized in 11 main research areas.

Finally, I would like to acknowledge the Head of Department for having strongly supported the birth of such publication, along with all the members of the Editorial Board, whose tenacious efforts in file revision and graphic design have made this publication possible.

Paolo Macini
Coordinator of DICAM Editorial Board
DICAM FIGURES

Department organization
Head of Department: Francesco Ubertini
Deputy Head of Department: Fabio Fava
Head of Administration Department: Vanessa Valisella
Department Board: Maria Bignozzi, Roberto Bruno, Vittorio Di Federico, Fabio Fava, Giada Gasparini, Andrea Munari, Virginio Pilò, Lorenza Pucci, Roberta Rizzolo, Federico Rupi, Giulio Cesare Sarti, Elena Toth, Alessandro Tognoli, Francesco Ubertini
Department Council: full professors, associate professors, assistant professors and Head of Administration Department, representatives of technical and administrative staff, representatives of research fellows and representatives of BS, MS and Ph.D. students
Chairmen of Committees: Research, Alessandro Paglianti; Education, Marco Savoia; Library, Andrea Munari; Laboratories, Andrea Simone; Editorial Board, Paolo Macini
Staff: Full Professors and Associate Professors (68); Ph.D. Students (85); Research Assistants and Research Fellows (89); Administration Staff (28); Lab Technicians Staff (24)

Laboratories
Laboratory of Bioreactors, Photocatalytic Processes and Applied Fluid-dynamics – LABIOFF
Laboratory of Computational Mechanics – LAMC
Laboratory of Environmental Biotechnology and Biorefineries – LABIOTEC
Laboratory of Geoengineering and Natural Resources – LAGIRN
Laboratory of Hydraulic Engineering – LIDR
Laboratory of Industrial Safety and Environmental Sustainability – LISES
Laboratory of Land Surveying and Geomatics – LARIG
Laboratory of Macromolecular Synthesis and Materials Characterization– LAMAC
Laboratory of Materials Science and Technology – LASTM
Laboratory of Membrane Processes, Bioseparations and Diffusion in Polymers – LABMEM
Laboratory of Road Constructions – LAS
Laboratory of Structural and Geotechnical Engineering – LISG
Laboratory of Transport Network – LART

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Web sites
www.dicam.unibo.it
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OVERVIEW OF THE INTERNATIONAL MASTER DEGREE PROGRAMMES

International two-year Master in Civil Engineering
The international two-year Master Programme in “Civil Engineering” (“Laurea Magistrale”), entirely taught in English, is open to students of any nationality.
The main goal of the Master is to educate professionals with the necessary in-depth scientific and technical knowledge in the field of Civil Engineering, within a multi-cultural educational environment. The programme is meant to prepare students with firm technical bases while nurturing decision-making and leadership potential. It prepares graduates to practice their profession at an advanced level and with a unique exposure to an international environment to better understand the global issues of Civil Engineering.
The programme is organized in core modules and curriculum courses.
The core modules, common for all students, aim at consolidating fundamentals and improving modelling capabilities in the classical areas of Civil Engineering, such as Structural Mechanics and Engineering, Hydraulics and Hydrology, Geotechnical Engineering, Road and Transportation Engineering.
Students will select their field of specialization within three different areas, opting for one of the following curricula:
- Structural engineering
- Infrastructure design in river basins
- Offshore Engineering (with a second year held in Ravenna Campus)
After the Master, civil engineers plan and design all types of buildings, houses, industrial plants, bridges, roads and railways, waterways and water reservoirs.
Besides these traditional activities, in industrialised and rapidly evolving societies, the skills of Civil Engineers are increasingly requested in the fields of territory planning and environment preservation. Moreover, the arising demand for safety and protection against natural and industrial risks is the framework in which the skills of Civil Engineers meet the continuously evolving needs of Civil Protection.
Main employers of civil engineers are national and international construction companies, engineering and consultancy agencies and, public authorities. Quite a number of civil engineers are self-employed and run their own company or office.

International two-year Master in Environmental Engineering, ERE (Earth Resources Engineering) Curriculum
The two-year Master Programme (“Laurea Magistrale”), entirely taught in English, is open to students of any nationality.
The central theme of ERE is the conscientious stewardship of our finite natural resources, namely minerals, fuels, energy, water, and land. Students taking ERE Programme will attain a broad background in environmental engineering and earth resources covering water resources, pollution prevention, energy, resource economics, recycling, waste and biowaste valorization, alternative and renewable raw materials, reclamation, and health. It prepares graduates to practice their profession at an advanced level and with a unique exposure to an international environment to better understand the global issues of environmental engineering.
ERE graduates will be prepared to move to higher levels of their careers, across a variety of industries and sectors. They will gain access to a wider range of positions both in engineering companies and in national and international government agencies.
Besides these traditional activities, in industrialized and rapidly evolving societies, the skills of Environmental Engineers are increasingly needed in the fields of territory planning and environmental conservation. Moreover, the rising demand for safety and protection against natural and industrial risks is the framework in which the skills of Environmental Engineers meet the continuously evolving needs of civil protection agencies.

The Laboratories support both teaching and research activities. During the courses and the preparation of the final thesis students will find in the laboratories and the facilities of the department a very interesting and exciting place to improve their knowledge and abilities.

For their second year, students enrolled in the ERE Programme will be able to choose “Offshore Engineering” curriculum, held in Ravenna campus, gaining the possibility to carry out internships and to develop research projects in the companies operating in the field.

**International two-year Master Programme in Chemical and Process Engineering, STEM (Sustainable Technologies and biotechnologies for Energy and Materials) Curriculum**

The conventional world-players, such as the chemical and Oil&Gas industry, are undergoing increasing innovation and internationalization, thus requiring global competences and higher qualifications from the chemical engineers recruited.

The STEM curriculum of the Master Degree in Chemical and Process Engineering (“Laurea Magistrale”), entirely taught in English, was built to meet these needs.

In the first year, courses deepen the understanding of fundamental concepts: advanced thermodynamics and transport phenomena, introduction to basic design, and introduction to industrial safety. In the second year, both compulsory and elective courses are offered on specialized topics, such as materials, energy and environmental processes and industrial biotechnologies.

Graduates of the programme will be prepared to work in numerous fields, including the conventional chemical and process industry (petrochemical, specialty chemicals, pharmaceutical), the widespread energy industrial sectors (up-stream and down-stream Oil&Gas, energy generation, green energy production), and many other specialized sectors (material production, food technologies, industrial biotechnologies, etc.).

The Programme includes the opportunity for students to carry out part of their Masters research project in the framework of the collaborative research project between the University of Bologna and private companies or various international research institutes.

For their second year, students enrolled in the STEM Programme will be able to choose “Offshore Engineering” curriculum, held in Ravenna campus, gaining the possibility to carry out internships and to develop research projects in the companies operating in the field.

Among the more important professional sectors addressed by Master studies in Chemical Engineering are:

The conventional Chemical and Process Industry, and in particular the petrochemical, polymers, specialty chemicals, and pharmaceutical sectors: this industry is characterized by increasing globalization and is steadily recruiting qualified chemical engineers throughout Europe.

The Energy sector: Oil&Gas, both up-stream and down-stream, strongly requires qualified chemical engineers for design and operation in a framework of growing complexity and innovation towards increasing sustainability and environmental compatibility.

The Material sector, with its development towards nanomaterials and smart materials requires qualified chemical engineers to answer the demand for innovation and life-cycle sustainability.
The Biotechnology sector, with its evolution towards large-scale production, has a growing requirement of qualified chemical engineers able to support the industrialization of biotechnological processes and their operations. The Environmental sector, with the growing development of processes for the recovery of wastes, the valorization of biomass and the implementation of safe and sustainable technologies, needs qualified chemical engineers as a necessary support to its large-scale operations.

**International two-year Master Programme in Engineering of Building Processes and Systems, HBR (Rehabilitation of Historic Buildings) Curriculum**

The innovation in both technical and organizational structure is increasing the complexity of the building process. The emergence of more stringent requirements and the intense penetration of new materials and technologies take special relevance in consolidation, recovery and rehabilitation of historic buildings, which is a market segment in steady expansion. The growing cultural value attributed to the existing building and the economic and environmental benefits associated with its conservation are expanding this market, whose further development fuels a demand for high-profile skills, able to meet its specific characteristics and constraints. The HBR (Historic Buildings Rehabilitation) international curriculum of the Master in Engineering of Building Processes and Systems was built to meet these needs of new professionals, able to integrate the functions traditionally found within the process, by focusing on the critical analysis of the historical heritage, the diagnosis of conservation conditions, the definition of procedures and techniques for consolidation and rehabilitation of the artefacts, by applying effective methods and solutions, compatible with the protection of the heritage characters. In the first year, courses are mainly oriented to address basic issues of the Master’s studies: History of Italian and European Architecture; Conservation Theory of Historic Buildings and Heritage Conservation; Survey of Historic Buildings, Materials and Technologies for Historic Buildings; Advanced Structural Mechanics and Mechanics of Historic Masonry and Wood Structures. Additionally, a Design Project course aims at training the students in applying to a case-study the acquired knowledge.

In the second year, both compulsory and elective courses are offered on specialized topics, such as Structural Diagnostics, Seismic Assessment and Rehabilitation; Geotechnical Engineering for the Preservation of Historic Buildings; Mineralogical and Petrographical Characterization of Natural and Artificial Stone Materials.

At the end of the program, a degree titled “Master in Engineering of building processes and Systems” (Laurea Magistrale in Ingegneria dei Processi e dei Sistemi edilizi, Classe LM-24) is awarded.

Graduates of the program will have the training to go on to work in numerous fields, including Public Administrations, Companies carrying out works of consolidation and recovery of historic buildings, and many other specific sectors, such as production of building components, diagnostic and survey services, facility management.

DICAM international Master Degrees include Dual Degree joint education Programmes with Columbia University in New York (Civil Engineering, ERE, STEM), the University of Miami (Civil Engineering, ERE) and Tongji University in Shanghai (HBR). Students participating in the Dual Degree may obtain in two years the International Master Degree (Laurea Magis-
trale Internazionale) at the University of Bologna and the Master of Science at the partner University.

New Dual Degree agreements are in the process of being established, namely with Université de Liège (Belgium) and USP (University of San Paulo, Brasil).

Completion of all Master Degrees can also lead to entering PhD. level studies.
PhD PROGRAMME

The Department provides a highly stimulating environment for PhD research and our doctoral programme attracts outstanding students from a variety of academic backgrounds. They form an integral part of the Department’s research life and numbers have risen to over 85 PhD students in 2013. At present, the Department manages a PhD Course in Civil, Chemical, Environmental and Materials Engineering (PhD@DICAM).

The course aims to provide the PhD candidates with the skills required by managing authorities, engineering offices, firms, companies, private and public research centres, etc. Moreover, the doctoral programme provides students with research experience, the opportunity to pursue advanced studies in engineering fields (broadly defined), familiarity with appropriate methods and theories, and participation in an active research community.

The scientific topics of PhD@DICAM are those characterizing the major disciplines in the field of Civil Engineering, Chemical and Process Engineering, Environmental Engineering, Materials Engineering and Industrial Biotechnologies.

The PhD course covers a 3-year period and helps the candidates to build up and improve their base and specialized knowledge, through the development of an original and autonomous research activity. Periods of study and research abroad are also expected.

Curricula and research areas
The PhD Course is characterized by several disciplines in which the research can be developed:

2) Structural and Geotechnical Engineering: Continuum Mechanics, Structures, Geotechnics.

Training: Our PhD training aims to provide students with a qualification of international standing that is suited for an industrial or academic career. To achieve this, we complement work on the research project with Departmental base courses or modules on relevant topics, shared by different curricula, and specialized courses specific for each educational path. Specialized courses are defined also according to the specific targets of the research activity developed by each candidate.

Research: Our PhD students are encouraged to interact with researchers working in different areas and are co-supervised by academics of the Department. Such interdisciplinary training fosters the intellectual capabilities and practical skills needed to cooperate with engineers and scientists from a variety of academic backgrounds.

Research is carried out in three phases. The first one is aimed at properly setting up the research program, through an accurate literature overview and the planning of the specialized courses, and usually takes place in the first year in parallel with the courses. The second phase consists
in an autonomous development of the research activity, through analyses, experimental tests and/or surveys in the field. This phase usually goes from the third to the fifth semester. The third phase is devoted to results dissemination and to the preparation of the final thesis.

Fabio Fava
Coordinator of PhD@DICAM
School of Architecture and Engineering, new Building, Via del Lazzaretto

School of Architecture and Engineering, historical building, Viale Risorgimento
RESEARCH PROJECTS AND ACTIVITIES 2015
DIFFUSION IN POLYMERS AND MEMBRANE SEPARATIONS
MEMBRANES AND MEMBRANE PROCESSES FOR LIQUID MIXTURES

RESEARCH GROUP: Serena Bandini, Carlo Gostoli, Valentina Morelli

KEYWORDS: membrane processes, liquid mixtures, process development, Nanofiltration, food industry

The activity focuses on membrane processes (Microfiltration (MF), Ultrafiltration (UF), Nanofiltration (NF), Reverse Osmosis (RO), Forward Osmosis (FO), Electrodialysis (ED)) for innovative separation and reaction techniques based on polymeric, inorganic and composite membranes for food, energy and process industry applications. Research activity is carried out on: i) experimental characterization of membrane properties and of membrane performances, ii) transport and partitioning phenomena modeling, iii) module performances characterization and iv) process development to industrial scale. The activities are in cooperation with international universities and industries and can be described as follows.

General assessment of NF modeling. Development of a partitioning-transport model of electrolyte/neutral solutes mixtures in NF membranes, accounting Donnan equilibrium, Dielectric Exclusion and hindered mass transport. The studies are based on a wide experimentation on membrane performances and electrochemical characterization of membrane material.

Nanofiltration in food industry. NF is a potential alternative to RO and UF for concentration operations. Pre-concentration of milk and/or whey for the production of iposodic cheese was developed. Separation of simple sugars from complex sugar mixtures and process development on industrial scale was patented in cooperation with a company. Separation of isomers by NF membranes is under investigation also.

New frontiers in membrane engineering. New methods for energy production, new apparatuses including reaction and separation steps, new compact devices to perform conventional unit operations without flooding, channeling or backmixing problems are among the future challenges. New inorganic and composite membranes are under investigation to produce energy by Forward Osmosis or Reverse Electrodialysis.
MAIN PUBLICATIONS


PATENTS


RESEARCH PROJECTS


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MEMBRANE CONTACTORS

RESEARCH GROUP: Serena Bandini, Carlo Gostoli, Felipe Varela Coredor
KEYWORDS: membrane contactors, mass transfer operations, membrane reactors, pertraction, wine processing

Membrane Contactors (MC) are mass transfer devices that allow two phases to come in contact without dispersion of one phase into the other. The membrane acts as a mere physical support for the interface and does not contributes to the separation through its selectivity, the separation being primarily based on the principle of phase equilibrium. The macroporous membrane, usually in the shape of hollow fibres, may be either hydrophilic or hydrophobic; the interface is immobilized at the pore mouth on the side in contact with the non-wetting phase, whereas the pores are filled by the wetting phase. Polymeric membranes were usually employed in membrane contactor studies and applications, especially Polypropylene and PVDF. Recently increasing efforts have been devoted to develop ceramic membranes, or hybrid membranes to get better chemical and thermal stability as well as higher mechanical strength. Membrane surface modification techniques to improve the hydrophobicity has also been investigated.

The research group performed fundamental investigation on mass transfer rate in MC, especially in the shell side of hollow fibre modules as well as in strictly related processes, as Membrane Distillation and Osmotic Distillation.

The applications considered are typical of chemical and process engineering as well as of food and biotechnology industry:
- recovery of bioproducts (Vanillin) from fermentation broths by using selective solvents;
- removal of Volatile Organic Compounds from aqueous streams and/or solvent recovery;
- membrane reactors: chemical reactions and stripping operations for absorbents regeneration at high temperature and average pressures;
- alcohol level adjustment of wines; production of alcohol free wine;
- juices concentration at room temperature.

Membrane contactor: operation concept with hydrophobic membranes.

Pilot plant for fruit juice concentration and ethanol removal from wine.
MAIN PUBLICATIONS


Bruni L., Gostoli C., Membrane Contactors in Wine Processing, in: BEKASSY-MOLNAR, BELAFI-BAKO, PERMEA 2007, Membrane Science and Technology Conference of Visegrad Countries, Siofok (H), Sept. 2-6 2007


RESEARCH PROJECTS

Attività di test di moduli di Membrane Contactors Ceramici - Progetto di ricerca n. 658283 Convenzione fra DICMA e SAIPEM (Milano), responsabile Serena Bandini, 2012-2014

Sviluppo di processi a membrana in Enologia, Convenzione tra DICMA e Juclas S.r.l. (Verona), responsabile Carlo Gostoli, 2011-2012

Dealcolazione di vini con tecnologie a membrana, Convenzione fra DICMA e Terranera S.r.l. (Grottolella, AV), responsabile Carlo Gostoli, 2007-2008.

Pilot plant for juice concentration by direct osmosis, CONFROD Project, 1999-2000, Progetto cofinanziato con fondi Europei nell’ambito della misura 1.6 (sviluppo dell’innovazione) Obiettivo 2, della Regione Emilia Romagna, responsabile Carlo Gostoli


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The aim of the research is the purification of biomolecules for therapeutic use, biomedical and biotechnology applications using affinity convective chromatography. In this area two classes of separations are considered: purification of biomolecules and selective apheresis. The research activity is both experimental and theoretical, with a particular emphasis on mathematical modelling.

The experimental activity is focused on the functionalization and characterization of membranes and other chromatographic supports for purification of virus, monoclonal antibodies, proteins and different biomolecules.

The choice of appropriate materials, membranes, ligands and spacer arms, is the first step towards the development of affinity membranes.

Ligand immobilization is the critical step of the process, since the ligand needs to maintain its functionality while immobilized on the support. The choice of the spacer arm, that acts as a linker between membrane and ligand is crucial for the process.

Affinity membranes are initially characterized in batch using pure protein solutions, then the protein of interest is purified from the complex solution (e.g. supernatant of cell culture or serum) where it originates.

The experimental characterization is mainly performed using a low pressure chromatographic system, FPLC, in which columns with the solid supports to be characterized (beads, membranes or monoliths) are operated. The relevant transport parameters and the kinetic parameters of adsorption and elution are determined from the experimental data, it is important to note that kinetic parameters need to be determined for every protein/ligand system.

A mathematical model has been developed for the description of the whole chromatographic cycle: adsorption, washing and elution. Model validation has been performed with experimental data obtained with a bench scale apparatus for different affinity systems, using both membranes and monoliths, with different proteins and ligands. Scale-up studies using the model as a predictive tool for bioprocess design are also performed.
MAIN PUBLICATIONS


RESEARCH PROJECTS

EU FP6 NMP3-CT-2004-500160, Project: AIMs “Advanced Interactive Materials by Design”.

IT PRIN 2008, Project: “Sviluppo di membrane di affinità per anticorpi monoclonali”.

CONTACTS

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Membranes based on polymeric materials are known to offer a selective ability towards different gases and vapours. Membrane separations represent a clean and economic way to replace traditional separation and purification technologies based on high pressure or temperature gradients and on phase change. The research activity focuses on the characterization and modeling of the gas permeation into commercial as well as innovative membranes in order to design specific separation processes and to optimize material properties. The research is carried out in combination both with the final users of the separation processes, either in the industrial or pilot plant scale, and with material manufacturers and chemists. Separation of interest include: CO2 removal from natural gas, biogas or flue gas, purification of hydrogen from steam reforming or from fermentation (biohydrogen), separation of hydrocarbons from light gases, etc. The research also includes macroscopic modeling of the mass transport properties allowing to gain a deep understanding of the separation process. The current activity is particularly focused on:

1) Polyimide membranes (e.g. Matrimid) which exhibit good thermal and mechanical properties and interesting performances in CO2/CH4 and CO2/N2 separations.

2) high free volume glassy polymers (PTMSP, polynorbornenes, polymer of intrinsic microporosity PIM, Amorphous Teflon), with high gas permeability and selectivity.

3) mixed matrix membranes based on glassy polymers and nano-sized silica particles that enhances the permeation rates of gases, with different effects on selectivity.

4) rubbery polymers based on ethylene oxide or propylene oxide with high solubility for CO2.

The lab is equipped with pure and mixed gas permeometers, balances and pressure decay devices for pure and mixed gas sorption. Also polymer swelling can be monitored. The research is carried on in collaboration with several Italian and Foreign groups.

Fig 1 a) effect of temperature and water absorbed on the gas permeability in Nafion® N117; b) effect of butane pressure and amount of silica filler on the butane permeability in Amorphous Teflon AF2400 mixed matrix membrane.
MAIN PUBLICATIONS


RESEARCH PROJECTS
BIOHYDRO 2010-2012: Combined biological production of methane and hydrogen from wastes of the agro-food industry


Convenzione CNR, progetto “Carbone pulito” PAR 2011.


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MEMBRANES FOR ENERGY APPLICATIONS

RESEARCH GROUP: Giulio C. Sarti, Marco Giacinti Baschetti, Maria Grazia De Angelis

KEYWORDS: proton exchange membrane fuel cells (PEMFC), ionomers, hydrogen, palladium membranes

The activity focuses on the study of novel techniques for the processing of new energy carriers (hydrogen) and the optimization of new energy production devices (fuel cells).

**Palladium Membranes for Hydrogen purification.** Hydrogen is one of the most promising energy carriers, due to its intrinsically clean combustion and possible use in fuel cells. Hydrogen is mainly produced by the reforming of natural gas; an efficiency increase in that process is a first step toward a more sustainable future. Palladium membranes can be used to purify hydrogen produced via steam reforming, reducing costs and improving efficiency of the whole process, due to high permeability and selectivity, and lower energy consumption than currently used systems (e.g. pressure swing absorber). Moreover membrane systems and can be assembled within the steam reforming reactor, to increase the reaction efficiency and yield.

The activity is aimed at testing and modeling transport of hydrogen-containing mixtures in palladium membranes, in order to design the most appropriate membranes and modules in a real separation environment, in the presence of poisoning gases, such as CO and water vapour.

**Ionomer Membranes for Fuel Cells.** Proton Exchange Membranes Fuel Cells (PEMFCs) are energy production devices that use hydrogen (or methanol) as fuel and polymeric membranes as electrolytes (e.g. Nafion®, Aquivion®). The membrane conductivity depends on the humidity absorbed and the study of mass transport through the membrane is essential for controlling its performance. The activity is focused at the experimental and theoretical study of fluid transport through membranes as a function of operative conditions and membrane properties, especially at temperatures above 60°C as they allow the use of alternative fuels and reduce electrode catalyst poisoning. The analysis is carried out with the aid of infrared spectroscopy, dry and humid gas permeometers, balances and pressure decay devices for sorption, TGA measurements.
MAIN PUBLICATIONS


RESEARCH PROJECTS

Sviluppo di una filiera integrata dell’idrogeno per lo sfruttamento delle fonti energetiche alternative e la decarbonizzazione. Funded within the “Accordo Programma Quadro tra il Ministero dello Sviluppo Economico, il Ministero dell’Università e della Ricerca e la Regione Emilia-Romagna - II Integrativo - Sostegno allo sviluppo dei laboratori di ricerca nei campi della nautica e dell’energia per il Tecnopolo di Ravenna” (2012-2013).


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The research activity on packaging materials started in early 2000s with the participation to National projects and networks aggregating different synthesis and characterization groups around the idea of building barrier nanocomposites as well as hybrid organic/inorganic coatings for traditional packaging materials. The goal was to reduce the amount of material required to protect the packaged goods against oxygen, humidity and other fluids passing through the film.

In 2004 the group joined a large collaborative FP6 project named SUSTAINPACK which was specifically devoted to the development of new, sustainable eco-friendly composite packaging materials based on natural substances: cellulose, polylactic acid, and so on. The activity on sustainable packaging as then never stopped and is still ongoing due to constant collaboration with other European entities within different european project such as the International training network NEWGENPAK and COST Action BIOMATPACK, as well as in collaborations with other Italian Universities.

In this research field the group is currently involved in the study of barrier properties of microfibrillated cellulose (MFC) and is highly specialised in the characterization of gas permeability in packaging materials, both in dry and humid conditions, as well as in the measurement of moisture absorption at different temperatures. Several modelling tools based on both numerical and analytical approach are available to describe the experimental data with particular reference to the case of nanocomposites materials. Apart from these activities in the same framework also other research are carried out such as the study of corrosion protective coatings or of polymer swelling during sorption.
MAIN PUBLICATIONS


RESEARCH PROJECTS

NEWGENPAK Marie Curie Initial Training Network: “New Generation of Functional Cellulose Fibre Based Packaging Materials for Sustainability”

BIOMATPACK COST ACTION “Impact of Renewable Materials in Packaging for Sustainability: Development of Renewable Fibre and Bio-based materials for New Packaging Applications”

FP6 Large Collaborative Project SUSTAINPACK (Innovation and Sustainable Development in the Fibre Based Packaging Value Chain)

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MODELLING SOLUBILITY IN POLYMERS

RESEARCH GROUP: Giovanni Cocchi, Matteo Minelli, Maria Grazia De Angelis, Marco Giacinti Baschetti, Giulio C. Sarti, Ferruccio Doghieri

KEYWORDS: solubility, glassy polymers, non equilibrium, thermodynamics, polymer solutions.

The solubility of fluids in polymers is relevant in many industrial applications such as membrane separations and packaging, as well as polymer processing and technology (desolventization, CO2 and solvent foaming). Starting from mid-1990s, the group has developed a model specifically devoted to the prediction of solubility in glassy polymers named Non Equilibrium Thermodynamics for Glassy Polymers (NET-GP) and the relative versions NELF, NE-SAFT, NE-PHSC which adopt the concepts of the Lattice Fluid (LF), SAFT and PHSC equations of state, respectively.

Such approach indeed adopts, to identify univocally the out-of-equilibrium state of the system, the density of the glassy phase, and allows to extend to the non equilibrium domains the most accurate equation of state (EoS) models available for polymeric systems, such as the Lattice Fluid theory (LF), the Statistical Associating Fluid Theory (SAFT) and the related Perturbed Hard Sphere Chain theory (PHSC) model. The system parameters can be taken from the literature, from experimental data or molecular simulations. The approach has been applied to the prediction of pure and mixed gas, vapor and liquid solubility in glassy polymers in a wide range of temperatures and pressures. The approach can be applied to homopolymers, polymer blends and block copolymers, as well as to composite materials (mixed matrix membranes), and can span at temperatures above and below Tg.

The approach can account for the effects of history and processing conditions on the sorption properties, and it has been recently implemented with molecular techniques to obtain the parameters of poorly characterized polymers. The model is downloadable from the group website and is interfaced to an user-friendly Excel spreadsheet, containing also a large database with the parameters of several fluids and polymers.

Fig. 1. below: CO2 solubility in blends of Polystyrene and Poly(phenylene oxide) (PS/PPO) at 35°C, lines are NELF model prediction based on binary mixture data only (PS-CO2 and PPO-CO2), reported in the figure above.

Fig. 2. Infinite dilution solubility coefficient of CO2 in polycarbonate at infinite dilution as a function of reciprocal temperature. Dashed line: SAFT EoS; Solid line: NE-SAFT model.
MAIN PUBLICATIONS


RESEARCH PROJECTS

PRIN 08: Characterization and macroscopic modeling of the thermodynamic behavior of binary and ternary polymers/solvent mixtures for the fabrication of biomedical devices through thermally induced phase separation (TIPS).


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Geoengineering and Natural Resources
MAGNETIC RESONANCE AND PETROPHYSICAL CHARACTERIZATION OF POROUS MEDIA

RESEARCH GROUP: Villiam Bortolotti, Paolo Macini, Ezio Mesini, Marianna Vannini

KEYWORDS: MRR, porous media, permeability, wettability, UPEN

Nuclear Magnetic Resonance Relaxometry (MRR) is a universally accepted technique for the spatially non-resolved determination of structural and transport properties of porous media in a non-destructive and non-invasive way. It is based on parameters like longitudinal and transverse relaxations time (T₁ and T₂, respectively) and magnetization density (M₀) and, nowadays, is widely used both in core and log analysis to determine petrophysical properties of rocks, such as porosity, pore size distribution, permeability, wettability changes and irreducible water saturation. Natural rocks are usually heterogeneous and this generally leads to multiexponential relaxation, which we have usually inverted by UpenWin software, to obtain the distribution of local Surface/Volume ratios.

UpenWin is a software for Windows internally developed that implements the UPEN (Uniform PENalty) algorithm and is distributed by the University of Bologna. UPEN is a robust algorithm for the inversion of multiexponential decay data, that allows appropriate smoothing of the distribution, allowing sharp peaks without breaking broad features into multiple peaks not required by the data.

Magnetic Resonance Imaging (MRI) is a spatially resolved method to get information on the distribution of oil or water into the porous medium and to follow flow and absorption of the saturating fluids. A powerful extension of the previous techniques is the Quantitative Relaxation Tomography (QRT), based on the combination of MRR with MRI. QRT generates relaxation time maps, i.e. images where the signal of each voxel (elementary volume, corresponding to the elementary 2D pixel in the image) is proportional to T₁ or T₂ or M₀ of the fluid in that voxel.

The research activity of this group is focalized on the use of both MRR and MRI techniques to characterize the petrophysical properties of the porous media, to monitor the saturating fluids flow and to quantify the interaction of the fluids with the surfaces of the pores space. Particularly studied are the wettability and the permeability of rocks, that mainly affects oil recovery, and natural and amended soils.
MAIN PUBLICATIONS


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ADVANCED METHODS FOR CHARACTERIZATION OF ROCK MATERIALS AND ROCK MASSES

RESEARCH GROUP: Annalisa Bandini, Paolo Berry, Daniela Boldini, Stefano Bonduà, William Bortolotti, Roberto Bruno, Marianna Vannini

KEYWORDS: nanoindentation, bimrocks, rockburst, Magnetic Resonance, Rock Impact Hardness Number

The research on the rock materials and rock masses characterization, in situ and in laboratory, covers a large number of themes and the main topics concern with:

a) rock materials
   • study of the relationships between microstructure and mechanical response of rocks under static and dynamic loading conditions;
   • determination of the nano and micromechanical properties through instrumented indentation techniques and scratching;
   • characterization of the rocks internal structures through Nuclear Magnetic Resonance (MRI images and NMR curves);
   • measurement of the acoustic emissions (AE) during compression and tensile tests, to study rockburst phenomena;
   • development of innovative and non-conventional investigation techniques to determine the strength of irregular shaped specimens;
   • non destructive characterization techniques (ultrasounds, dye penetrant inspection, image analysis);

b) rock masses
   • characterization of the mechanical strength of structurally complex rock masses (bimrocks).

In the research activities, in addition to standard investigation techniques, non-conventional tests are specifically designed for particular applications and issues. With regard to non-conventional tests, a strength index (Rock Impact Hardness Number), a procedure for AE monitoring of rock samples under compression and instrumented indentation techniques, totally innovative in the Rock Mechanics field, have been developed.

As concerns the rock masses, the research group has designed and performed non-conventional shear tests (Bim Test) for bimrocks. Moreover, the research team also utilizes a 3D camera probe for cored and drilled holes, to examine the rock masses structures, with continuous logging and a software for images processing.
MAIN PUBLICATIONS


RESEARCH PROJECTS

PRIN 2007 Advanced techniques for monitoring and characterizing mine and quarry activities to preserve the safety and the environment during exploitation. National Coordinator: Prof. P. Berry.

Joint Research Project between Dept. of Earth Sciences-University of Firenze and DICAM-University of Bologna on “Scientific support regarding the engineering aspects related to the Allori panel, in the framework of the 3rd Operative Agreement between the Dept. Earth Sciences and ENEL Production S.p.A. Gem/Business Unit Santa Barbara, related to the mining site of Santa Barbara (AR)”. Coordinator: Prof. P. Berry.

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HIGH ENTHALPY – LOW ENTHALPY GEOTHERMAL RESERVOIR

RESEARCH GROUP: Paolo Berry, Stefano Bondùa, Villiam Bortolotti, Roberto Bruno, Carlo Cormio, Sara Focaccia, Francesco Tinti, Ester Maria Vasini.

KEYWORDS: geothermal numerical model, simulation, GIS, heating & cooling, heat pumps

The best practice to exploit high enthalpy geothermal reservoirs also entails the design, development and use of numerical codes for simulation works. Usually, the geothermal reservoir is fractured and a non isothermal flow of multicomponent multiphase fluids, with in case mass exchange, is present. At present we use iTOUGH2 (a flexible and robust numerical geothermal simulator extensively used all over the world) for research and commercial activities. Nowadays, there are much commercial and non-commercial software that manage and display the input-output data of iTOUGH2, but in general there are severe limitations on the use of unstructured grids. The group has therefore developed an integrated software system to facilitate the mesh creation and population of irregular grids based on the customization of the open source GRASS GIS and an in-house 3D viewer written in JAVA.

The use of the underground as geothermal reservoir where storing and retrieving thermal energy is the field of low-enthalpy geothermal energy, in which the research team has been engaged during last five years, nationally and internationally. The main applications deal with heating and cooling of residential and industrial buildings. The main contributions concern the modeling of petro-physical properties of the reservoir and its interaction with the geo-heat exchanger systems, by the use of geostatistics (GEO-MS) and numerical modelling (FEFLOW, COMSOL). Recently, methodologies of hydrocarbons to the characterization of shallow geothermal reservoir have been applied for the joint simulation of heating and cooling systems based on geothermal heat pumps. A top application regards Thermal Response Test (TRT); a new methodology of analysis based on a probabilistic modelling has been proposed at the international level. The team adheres to the Committee for Energy Conservation through Energy Storage of the International Energy Agency (IEA-ECES) and has collaborated in the drafting of the final document of Annex 21, Subcommittee for TRT.

Fig. 1. Irregular grid, overlapped to a digital elevation model and a geothermal wells map (red dots) created with GRASS GIS.

Fig. 2. Scheme of shallow geothermal system based on a vertical borehole heat exchanger.
MAIN PUBLICATIONS


RESEARCH PROJECTS

EuropeAid Project – Energy for Eastern Mayors (E4EM). DICAM Lead Partner.

Characterization of underground thermal properties for geothermal applications in rural context. Collaboration with Agronomics School – UNIBO.


MAC – GEO Project financed by Tuscany Region. “Modellazione matematica di sistemi geotermici per la definizione di strumenti di decisione da utilizzarsi nelle procedure di controllo di concessioni geotermiche”, in collaboration with University of Florence, CINIgeo and CNR.

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The mineral raw materials are the basis of any process of economic development of man. The team deals with the characterization, modelling, selection and exploitation of mineral deposits and deposits of industrial materials. Specific topics are the spatial variability studies and modelling of useful substances and of petrophysical properties of the materials, the optimization of their sampling, the selection of the exploitable resources, technically and economically. Geostatistics is one of the major theoretical frameworks adopted; estimated and simulated models are typical tools used. The best international geostatistical software is available (ISATIS, ...) besides its own library.

In the sector of ornamental stone characterization, in the last 15 years the team coordinated or was partner of several international projects supported by the European Union (COSS; OSNET; FARO). In this field, an original technology was developed, and then patented, for the characterization of ornamental stone by image analysis. An advanced image processing of the surface of slabs and tiles can achieve goals related to aesthetics, such as quality certification, certification of origin, the automatic selection of different products and the degradation analysis.

The research topics in the sector of exploitation of raw materials are mainly focused on:
- planning and design of mining activities, at national and local scale;
- processes of selecting the most appropriate methods for mining;
- environmental impact assessment and monitoring of surface and underground mining;
- safety in underground, namely for methane emissions during stopes and excavations;
- reclamation aspects in planning and design;
- reclamation modelling and requalification projects;
- rehabilitation of abandoned mines and quarries.

Design software for ventilation networks, blasting, environmental control for open pit mining, was developed. In situ tests are done by advanced technologies (laser scanner, satellite images) and environmental controls are carried out (seismicity induced by blasting, overpressure).
MAIN PUBLICATIONS


RESEARCH PROJECTS


PA Terni - “Guidelines for the identification, characterization and quantification of mineral deposits of the second category” 2009-2010.

ARPA PUGLIA, 2011, “Individuazione di modelli di gestione pubblico-privato e criteri di selezione per il recupero di paesaggi degradati a causa delle attività estrattive dismesse”.

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Drilling engineering research concerns the study of bit performance evaluation, the analysis of inhibitive drilling fluid and the optimization and testing of new formulations of fluids utilized in trenchless (or no-dig) drilling. Drill-bits are the most important tools utilized in oil and gas well drilling. Bit selection is vital from both the technical-economic standpoint, and for the optimization of the drilling process, since it can save drilling and roundtrip time. The research implemented a novel approach to bit performance evaluation, based on the analysis of large databases and the definition of a new drilling model, allowing the comparison of specific energy, cost per meter and a Bit Index, taking into account a large combination of drilling parameters, including a more precise lithological description of the well. Drilling fluid properties are the key element of any drilling operation. The principal studies concern the formulation and the rheological study of fluids utilized in trenchless drilling, whose purpose is the installation of a pipeline in the subsoil by limiting the excavation of open pits. Lab evaluation and characterization of new drilling fluids have been performed in laboratory and tested in the field. Another field of research is the evaluation of clay inhibitive effects of water based drilling fluids containing non-toxic additives (polymers, glycols and inorganic electrolytes), formulated to reduce the mechanical instability of clay formation during drilling. The environmental research concerning exploitation, production and utilization of hydrocarbons is twofold. On one side there are studies on environmental sustainability of the upstream industry, aimed to the implementation of strategies of sustainable management of hydrocarbon production in environmentally sensitive areas. On the other side, research is focused on anthropogenic soil subsidence caused by underground fluid withdrawals. The research activity of the Department concerns both regional subsidence studies (including modelling) and specific researches on measurement techniques, and in particular extensometric and in-situ Radioactive Marker Technique measurements.
MAIN PUBLICATIONS


P. Macini, L’eredità dell’incidente nel Golfo del Messico e le tecnologie per la sicurezza nell’industria petrolifera, 1° Congresso dei Geologi di Basilicata; Ricerca sviluppo e utilizzo delle fonti fossili: il ruolo del geologo, Potenza, 30 Nov.-2 Dic. 2012.


RESEARCH PROJECTS

P. MACINI, Scientific coordination of several Research Contracts signed between the University of Bologna and Eni S.p.A., Div. E&P concerning research themes related to drill bit performance evaluation.

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The research activity of the group concerns the study, the development and the use of numerical codes for the simulation of hydrocarbons and other underground fluids reservoirs, including the study and the modelling of pollutant transport in ground water.

Among other experimental research in the field of reservoir engineering, petrophysics and rock mechanics are the following:

- Non-Darcy flow in porous media, observed in gas wells when the fluids converging to the wellbore attains the velocity peculiar of turbulent flow. In that case the use of Darcy law would lead to inaccurate production performances evaluation.

- Measurement of rock compressibility at great depth, at confining pressure up to 150 MPa. The experimental apparatus has been designed to perform both static and dynamic measurements.

- EOR and wettability reversal studies, including lab studies on reservoir rock and fluid properties (interfacial tension, wettability, etc.). Flooding efficiency curves are obtained and used as a criterion to evaluate the performance of wettability reversal, which seems to improve oil recovery in fractured carbonate reservoirs, where oil cannot be economically produced.

- CCS application (reservoir assessment, site evaluation, injection modeling). The widespread application of CCS depends on technical maturity, costs, overall potential, diffusion and transfer of the technology to developing countries and their capacity to apply the technology, regulatory aspects, environmental issues and possible problems of public perception and acceptability.

- Hydraulic conductivity of rocks and soils, featuring experimental studies on the physico-chemical interactions occurring between saturating fluids and permeability of natural porous media. These studies are aimed to aid the design of waste disposal sites (with potential release of bottom liquids), including safety criteria management. Other theoretical and lab studies concern the relationships between petro-physical properties of porous media, with particular reference to the effects of grain size distribution and porosity on hydraulic conductivity of soils or loose formations.
MAIN PUBLICATIONS


V. Bortolotti, P. Macini, F. Srisuriyachai, Wettability Index of Carbonatic Reservoirs and EOR: Laboratory Study to Optimize Alkali and Surfactant Flooding, Paper SPE 131043, CPS/SPE International Oil & Gas Conf. and Exhib. in China., Beijing, 8-10 June 2010.


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ENGINEERING AND SAFETY OF EXCAVATIONS AND UNDERGROUND CONSTRUCTIONS

RESEARCH GROUP: Annalisa Bandini, Paolo Berry, Daniela Boldini, Valentina Fargnoli

KEYWORDS: tunnels, safety of excavations, seismicity, soil-structure interaction, numerical modelling

The research related to underground constructions covers many different topics and aspects of tunnelling, the most important and recent being:
- the tunnelling-induced subsidence and the interaction with surface structures
- the seismic behaviour of tunnels
- the soil-lining interaction in deep tunnels, especially in squeezing conditions
- the influence of hydro-mechanical coupling on tunnel behaviour
- the interaction between tunnelling and landslides
- the air overpressures and seismicity induced by blasting and excavation activities to underground and surface structures
- the excavation of tunnels in rock masses with methane
- the analysis of the geomechanical and technological parameters affecting the TBM excavation rate

The activity is developed using both numerical analysis and experimental investigations.

As concerns the numerical modelling, special emphasis is dedicated to the implementation of advanced constitutive models for soil, to the correct simulation of construction stages extending also the investigation to three-dimensional conditions and to the appropriate representation of the structural systems, those latter being the typical lining and support elements placed after the excavation or the buildings and monuments located at the ground surface. The results of the numerical simulations are most of the time validated against real case-histories and monitoring data.

In situ new investigations approaches and technological innovations for tunnel excavations are under development. With reference to safety, the research group has been involved in the definition of 44 suggested methods of “best practice” for safe working in tunnelling, adopted by the regions Emilia Romagna and Tuscany. These recommendations have been applied so far in approximately 200 km of tunnels of TAV and VAV projects.
MAIN PUBLICATIONS


RESEARCH PROJECTS

PRIN 2006. Effetti sismici sulle costruzioni in sotterraneo.


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TRANSITION ENGINEERING AS NEW APPROACH FOR DESIGN AND MANAGEMENT IN AN ENVIRONMENTAL, SOCIAL AND ECONOMIC SUSTAINABILITY

RESEARCH GROUP: Alessandra Bonoli, Luca Antonozzi, Francesca Cappellaro, Andrea Conte, Sara Rizzo, Anna Zanchetta e Sara Zanni

KEY WORDS: LCA, ecological footprint, water, recycling, green technologies

The team of Engineering of Transition is developing research activities oriented to building a sustainable world, from the point of view of environmental, social and economic, by saving and valorizing natural resources: raw materials, water and energy. Several themes of study and research to support design and management, in urban and industrial context, that can be summarized as follows:

→ treatment, valorization and recycling of raw materials and solid waste;
→ water supply, water and groundwater saving, wastewater recovery and recycling in relation with urban, industrial and agricultural uses;
→ energy recovery from solid waste and study of environmental impacts and waste production in relation with renewable energy sources;
→ research of unconventional or recycled materials for building and construction: recycled aggregates from demolition, utilization of straw, hemp, raw land, etc. for energy savings and to reduce climate-change emissions, for zero impact buildings, and in relation to greater simplicity in the process of rebuilding in areas affected by seismic events;
→ support to technological innovation in industrial R&D by recycling, savings and minimizing of environmental impacts: Ecodesign, Life Cycle Assessment and Life Cycle Cost Analysis, evaluation of Ecological Footprint, Carbon and Water footprint, multicriteria analysis and risk analysis in several production issues and in many environmental engineering activities (soil and polluted water reclamation, resources use and saving, waste management, etc.)
→ application of the concepts of resilience, green technologies and “site specific” design in rural and urban areas in order to reduce climate-change emissions and to save water, energy, soil and natural resources.

A specific stream of research concerns the application of all these researches and studies in cooperation activities for emerging and developing countries.
MAIN PUBLICATIONS


RESEARCH PROJECTS
Climate KIC - Pioneers into Practice. European Institute of Innovation and Technology.
EU Minotaurus Project 7th Framework Programme under Grant Agreement no. 265946.
Management and recycling activities of post-earthquake waste. Emilia Romagna Region.

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ANALYSIS AND MITIGATION OF LANDSLIDE RISK

RESEARCH GROUP: Lisa Borgatti, Federico Cervi, Guido Gottardi, Alberto Landuzzi, Marco Ranalli, Laura Tonni

KEY WORDS: landslide, risk, slope stability, slope stabilization, Alps, Northern Apennines

The deformed and displaced units which compose the fold-and-thrust belts of the Apennines and the Alps show a prominent predisposition to landslides. Research on large landslides from the recent past enables to better understand the geomorphological evolution of our territory, and in particular to evaluate the hazard related to dormant phenomena prone to reactivation. Our research methodology, taking advantage of modern technologies for data acquisition and representation, consists of the following stages: 1. detailed geological and geomorphological survey, to reconstruct stratigraphy and structure of the landslide sites; 2. archive research, to find any historical evidence of sliding events; 3. prehistorical landslides dating, by means of physical and incremental methods; 4. reconstruction of the slope geometry, also with reference to pre-landslide conditions, with photogrammetric and laser scanning techniques; 5. construction of longitudinal and transversal sets of geological cross-sections; 6. cross-section calibration by means of subsurface data; 7. 3D reconstruction of the sliding surfaces, by interpolation of altitude data drawn from outcrops and cross sections; 8. cross-section restoring and possible reconstruction of the pre-sliding slopes, taking into account any available historical evidence; 9. geotechnical modelling and slope stability assessment by back-analysis, also by means of probabilistic methods; 10. development of Bayesian analysis techniques as means of probabilistic calibration of the models and statistical update of the data; 11. monitoring of active movements by means of topographic, inclinometric and piezometric readings, also in real-time; 12. numerical modelling aimed at the design of structural mitigation countermeasures; 13. overall description of landslide evolution, from the precursors to the main event and the subsequent reactivations, including those expected for the next future; 14. analysis of the relationships between landslide occurrence and environmental factors at the Holocene temporal scale, with particular reference to climate and human interventions, also in archeological contexts.

Fig. 1. Ca’ Lita (RE), April 2004 – 3D model of the landslide after its total reactivation.

Fig. 2. San Leo (RN). Northern sector of the slab, affected by rock falls and earth flows.

Fig. 3. Baiso (RE). Ustable slopes in varicoloured clayshales.
MAIN PUBLICATIONS


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In the mountain range bounded to the S by the Mugello and Casentino basins, to the W by the Sillaro valley and to the E by the Conca valley, a study of the tectono-sedimentary relationships between the Umbria-Romagna foredeep and the Liguride nappe allows to define accurately chronology and style of the Apennine deformation. We recognise synsedimentary gentle folds and postdepositional thrusts in the foredeep succession, low angle normal faults confined within the nappe, and high angle normal faults offsetting the whole Apennine stack. The latter are connected to exumation and dismembering of the stack itself. Our research, carried out in collaboration with BiGeA – University of Bologna, focuses at the following subjects: (1) Age determination and physical correlation of the marker horizons in the foredeep successions of Mugello and Alta Romagna, along with detection of time-equivalent surfaces in the semi-allochthonous succession. (2) Characterisation of synsedimentary folding in the inner part of the Umbria-Romagna foredeep. (3) Structural and physiographic reconstruction of the Miocene Apennine front, by the study of olistostromes and their peculiar sedimentary covers. (4) Analysis of reactivations and displacements of the Liguride overthrust. (5) Mapping and interpretation of the low angle normal faults confined within the Liguride nappe. (6) Study of the relationships between recent uplift and the high angle normal faults which offset the whole Apennine stack. Our research is based upon the classical techniques of mapping and elaboration of stratigraphic and tectonic data. Seismic profiles and borehole data provided by hydrocarbon exploration companies are used for calibration at depth of geological cross-section (collaboration with public institutions and private enterprises).
MAIN PUBLICATIONS


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The research is focused primarily on groundwater, on the one hand assessing and characterising water as reserve and resource, on the other hand in terms of hazard and risk, with reference to slope instability and flooding. Hydrogeological monitoring in mountainous areas is aimed at assessing rainfall infiltration and the amounts of groundwater stored inside the aquifers, together with their hydrodynamic properties. The study is carried out with a multidisciplinary approach, using also hydrochemistry and isotopic geochemistry. One of the most promising topic, is the study of the hydrological and geotechnical characteristics of complex landslides in clay-rich slopes (assessment of hydrogeological, chemical and isotopic variations following rainfall and infiltration processes, numerical modeling of infiltration processes and flow, deformation and slope stability).

In plain areas, the main focus is on flood mitigation measures and their interactions with groundwater. This problem is worthy of research as during the last decades, a large number of flood control reservoirs were built in Emilia Romagna, in order to mitigate flood risk in urban areas. Besides this main purpose, the need for a multiple exploitation of the water stored in the reservoir is becoming of paramount importance, as a consequence of unusual drought periods and also as a source of alternative of energy production. In order to change what was the original designed destination, i.e., reservoirs that would have been filled for short periods and only in case of high return period flood events, a series of field and lab experimental data are needed, primarily to assure the stability of structures (dam, levees, eventual flood gates etc.) and also to check for possible negative effects, with particular reference to the risk of groundwater pollution and of base flow modifications. Therefore, a multidisciplinary research has to be undertaken, to collect hydrological, geological, hydrogeological and geochemical data, that are the basis of conceptual and numerical model that have to be developed in order to understand the interactions between the reservoir and the aquifer, in different scenarios.
MAIN PUBLICATIONS


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PHYSICAL AND NUMERICAL MODELLING OF THE BEHAVIOUR OF FALLING ROCK PROTECTION BARRIERS

RESEARCH GROUP: Guido Gottardi, Laura Govoni, Alessio Mentani, Francesco Ubertini, Cristina Gentilini, Stefano de Miranda
KEYWORDS: rockfall, risk mitigation, passive systems, physical modelling, FEM

Risk analysis and mitigation of very fast slope movements is the context of the research that addresses the physical and numerical modelling of passive systems against falling rocks and is especially focused on falling rock protection barriers, metallic structures designed to intercept and stop falling rocks along a slope. Such topic is currently of great interest, also following the recent publication of the “European Guideline for Technical Approval of falling rock protection kits” (ETAG 027). The research has involved the physical modelling of flexible falling rock protection barriers of high energy absorption capacity (from few hundreds to more than 5000 kJ) to investigate the highly non-linear mechanical response of these complex metallic structures in dynamic conditions. Tests were carried out in the full-scale test site located in Fonzaso, near Belluno in Italy, in collaboration with the Consorzio Triveneto Rocciatori and the Officine Maccaferri. Results of these tests, in which a free-falling concrete block (of velocity about 25 m/s and weight from 5 kN to 160 kN) impacts a prototype of barrier, have enabled the set-up of a reliable and consistent database and have provided a convenient starting point for the development of several non-linear and dynamic FE models. Such models have recently led to the development of a general and efficient strategy for the numerical modelling of these structures. In collaboration with the Autonomous Province of Bolzano, the numerical strategy has been also successfully applied to investigate the behaviour of other models of falling rock protection barriers with low energy absorption capacity (less than 200 kJ), widely used but not adequately studied.

The research is currently developed along two main directions: 1) structural design optimization, with special emphasis on the foundations and 2) definition of a computational tool taking into full account the effect of these structures in typical procedures of rockfall risk analysis and mitigation, with particular interest on the barrier actual working conditions.

Fig. 1. Impact test on a falling rock protection barrier prototype.

Fig. 2. FE model of a falling rock protection barrier under full-scale testing conditions.
MAIN PUBLICATIONS


RESEARCH PROJECTS
Research and consulting contract with Consorzio Triveneto Rocciatori, Belluno, Italy (2006-2008). Investigation of the behaviour of falling rock protection barriers from the results of full-scale impact tests. Scientific Coordinator: Guido Gottardi.


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GEOTECHNICAL CHARACTERIZATION OF NATURAL SOILS BY IN SITU TESTING

RESEARCH GROUP: Guido Gottardi, Laura Tonni, Michela Marchi, María Fernanda García Martínez

KEYWORDS: piezocone, silty soils, soil compressibility, riverbank seismic stability, partial drainage

In situ testing plays a crucial and effective role in subsoil geotechnical characterization. Since early '90s, the DICAM Geotechnical Engineering Lab has been equipped with a Delft Geotechnics piezocone device, installed on a suitably arranged and fully dedicated independent lorry, fitted for continuous and automated data acquisition. Significant efforts have been put on the refinement of testing procedures and on the improvement of measurement interpretation.

In last years, research in this area has been mainly based on the extensive piezocone testing campaign performed at the Treporti Test Site (Venice, Italy) within a long-lasting and comprehensive research project funded by the Italian Ministry of Research and carried out in cooperation with the Italian Universities of Padova and L’Aquila. The project aimed at better understanding the stress-strain-time response of the heterogeneous, predominantly silty sediments of the Venetian lagoon and similar intermediate soils, for which little information can be generally found in the geotechnical literature.

The large amount of piezocone data thus available has been interpreted with particular reference to the evaluation of compressibility characteristics of silts and silt mixtures, which have been found not to follow the framework published for other soils.

In the context of intermediate soils, research has also focused on the issue of partial drainage detection during cone penetration. Indeed, in these soils, different degrees of drainage are very likely to occur under a standard rate of penetration and the preliminary evaluation of such condition turns out to be of crucial importance for the assessment of representative mechanical parameters. Accordingly, piezocone tests at non-standard penetration rates have been performed in the silty soils of the Venetian lagoon as well as in other sites of the Emilia-Romagna region.

More recently, the research group has been involved in the geotechnical characterization, by in situ testing, of the sediments forming the banks of the Po river and the surrounding subsoil, within a research project aimed at verifying the seismic stability of the embankments.

Fig. 1. Profiles of the corrected cone resistance $q_c$, soil behaviour type index $I_{cn}$, and normalized cone resistance $Q_{tn}$ for a piezocone test performed at the Treporti Test Site.

Fig. 2. Typical stratigraphic section of the Po river embankments.
MAIN PUBLICATIONS

RESEARCH PROJECTS

Research and consulting contract with AUTORITÀ DI BACINO DEL FIUME PO. Evaluation of the seismic stability of the Po riverbanks in the Emilia-Romagna area.

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MODELLING OF GRANULAR SOIL BEHAVIOUR IN STATIC AND SEISMIC CONDITIONS

RESEARCH GROUP: Laura Tonni, Guido Gottardi

KEYWORDS: constitutive models, Generalized Plasticity, sand, liquefaction, numerical modelling

Due to the increasing complexity of geotechnical problems to be analysed, over the last years a considerable amount of research has been carried out on the constitutive modelling of soils. The attention of this research group has been mainly focused on the constitutive modelling of sands and sandy silts, within a rather versatile theoretical framework known as Generalized Plasticity.

In this context, an existing Generalized Plasticity formulation for sands (Pastor, Zienkiewicz & Chan, 1990), specifically developed to describe many important features of granular soil behaviour in both monotonic and cyclic loading conditions, has been assumed as a base.

The specific research activity of the team has mainly focused on the following two main areas:

1) A number of modifications and refinements, based on the state parameter concept in conjunction with the Critical State framework, have been introduced into the original constitutive equations, in order allow unified modelling of soil behaviour over a wide range of stress levels and void ratios. A significant application of such model has concerned the modelling of the complex mechanical behaviour of silty sediments of the Venetian lagoon basin.

2) A great amount of work has dealt with the implementation of Generalized Plasticity models into FE codes and especially on the development of robust and accurate integration schemes of the rate constitutive equations. Special emphasis has been given to the implementation of the Pastor-Zienkiewicz-Chan formulation. Typical applications of the model to general boundary value problem analyses have concerned the numerical modelling of initiation mechanisms of landslides, with special reference to catastrophic failures due to seismic-induced soil liquefaction or debonding phenomena in collapsible, weakly cemented soils.

The whole research has been carried out in close cooperation with Spanish researchers of the Centro de Estudios y Experimentación de Obras Públicas (CEDEX, Madrid).

Fig. 1. (a) Soil layer problem and seismic input; (b) Evolution of mean effective stress $p^e$ at different soil column points; (c) Evolution of excess pore pressure at different soil column points.
MAIN PUBLICATIONS


RESEARCH PROJECTS


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MODELLING THE RESPONSE OF SHALLOW FOUNDATIONS UNDER GENERAL LOADING
RESEARCH GROUP: Guido Gottardi, Laura Govoni, Michela Marchi
KEYWORDS: soil-structure interaction, macroelement, stability of equilibrium, off-shore foundations, towers

The response of shallow foundations subjected to combined loading has been intensively investigated for the last two decades. The understanding of their behaviour is crucial in many structural and geotechnical applications, not only off-shore like wind turbines, but also for other structures like gravity walls, chimneys, historical towers (Fig. 1). Among the most innovative and advanced analysis methods, the so-called Macro-element models enable to apply the external resultant forces (V, M/B, H) and displacements (w, 6B, u) to the whole foundation and surrounding soil system, as generalised stress and strain variables (Fig. 2). This conceptual framework is simpler and more intuitive than the well-known finite element methods and, at the same time, it is more rational and consistent with the cultural background of the civil engineer.

The research group has worked for many years on these topics, moving from extensive experimental campaigns involving several 1g and centrifuge tests carried out on shallow and embedded footings. These data have been interpreted through simple elastic, hardening-plastic models which are able to reproduce a footing response to general loading conditions with success. These models have been also modified to accommodate other important phenomena such as the soil creep and have been used to explore the stability of historical towers, whose soil-structure interaction is strongly time dependent. More recently the research group is exploring the use of more sophisticated constitutive models which can be model the footing response to other loading condition, such as cyclic or dynamic. The research group is currently planning further experimental tests to develop such models.

The research has been carried out in collaboration with the University of Southampton, the Oxford University, The Centre for Offshore Foundation Systemsof Perth (WA), the Politecnico of Torino.

Fig. 1. Two examples of structures with shallow foundations under combined loading: wind turbine and historical towers (in the picture a scheme of a wind turbine and the ‘Two Towers’ in Bologna).

Fig. 2. Yield surface of a surface footing on sand in the 3D space of applied loading components.
MAIN PUBLICATIONS


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Industrial and Environmental Biotechnologies and Fluid-Dynamics
The research is dedicated to the biotechnological production of bio-based compounds and biomaterials. To that aim, two main strategies are followed: (a) the exploitation of microorganisms collected from non-conventional environments, which could represent a ‘reservoir’ of microbial diversity and hence of new compounds and bioactive molecules; (b) the valorization of agro-industrial waste through the recovery and/or the transformation of their organic fraction. Bacteria adapted to the extreme environmental conditions could be a resource of new pigments that can be used as natural colorants, biosurfactants for the stimulation of the bioremediation of xenobiotics-contaminated marine sites, or extracellular enzymes that can be exploited in industrial processes. Microbiota actually taken into consideration are those from extreme environments including desert sand/rocks, inland (‘Chott’) or coastal (‘Sebkha’) saline systems in the south of Tunisia, and several polluted sites in the Mediterranean Sea.

Target residues to be valorized are: (i) wastewaters from the industrial production of olive oil, wine and cheese, and (ii) bran. If wastewaters contain high added-value compounds, they are pre-treated according to solid-phase extraction procedures for the recovery of such molecules (e.g., polyphenols occurring in olive mill wastewaters, which are natural antioxidants employed in several industrial fields). Wastewaters are employed as the feedstock for the biotechnological production of polyhydroxyalkanotes (PHAs), i.e., microbial biopolymers whose mechanical properties are similar to those of polypropylene. Wastewaters are previously digested under anaerobic acidogenic conditions for the production of volatile fatty acids, which represent a suitable substrate for PHA production. Bran is enzymatically hydrolyzed for the recovery of ferulic acid and its conversion into biovanillin via microbial conversion, after ferulic acid purification from carbohydrates (to be employed as the carbon source for the bioconversion process), and fructooligosaccharides (FOS) with prebiotic properties.
MAIN PUBLICATIONS


RESEARCH PROJECTS

EU FP7-KBBE-2010-4 Project ID. 266473: ULIXES (Unravelling and exploiting Mediterranean Sea microbial diversity and ecology for xenobiotics’ and pollutants’ clean up).

EU FP7-KBBE-2009-3 ID 245267 Project: NA-MASTE (New Advances in the integrated Man-agement of food processing waste in India and Europe: use of Sustainable Technologies for the Exploitation of byproducts into new foods and feeds).

EU FP7-KBBE-2010-4 ID. 265669 Project: ECOBIOCAP (Ecoefficient Biodegradable Com-poste Advanced Packaging).

EU FP7-2012-ID 311933 Project: WA-TER4CROPS (Integrating bio-treated wastewater with enhanced water use efficiency to support the Green Economy in EU and India).

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The research has the objective of finding solutions to the environmental problems linked to the production and consumption of plastics, which are obtained on the industrial scale from fossil sources and accumulate in the environments in which they are disposed, because of their scarce biodegradability. To this aim, the exploitation of renewable resources for the production of microbial biodegradable biopolymers, which could replace conventional plastics in defined applications, can represent a strategic approach. In particular, polyhydroxyalkanoates (PHAs) are polyesters, which are stored by several aerobic bacteria as a carbon and energy source under a metabolic stress due to the lack of one or more nutrients. To date, PHAs are industrially produced by employing sugars obtained from dedicated crops. The research objective is the substitution of such substrates with typical wastes of the Mediterranean basin, such as olive mill wastewaters and winery waste. The residue organic material has to be converted in volatile fatty acids (VFAs) within acidogenic anaerobic digestion processes. The biodegradation/valorization of waste plastics represents a further possible strategy to the aims described above. The research activity deals with the development of experimental procedures for the selection of novel and robust microorganisms, both as pure cultures and mixed consortia, able to attack polyethylenes, polypropylenes, polystyrene and polyvinyl chloride. For this purpose, actual-site aged plastic wastes obtained from landfills, terrestrial and marine sites will be utilized as sources of microorganisms potentially able of biodegrading plastics. Such microorganisms will be isolated and their biodegradation activity will be compared with those of private pure bacterial strains purchased from public culture collections. The opportunity to have controlled depolymerization of some polymers by selected enzymes to get oligomers to be reused in new or hybrid polymer production is also being evaluated.
MAIN PUBLICATIONS


RESEARCH PROJECTS
EU FP7-KBBE-2012-3.5-02 Project ID. 312100: BIOCLEAN (New BIOtechnological approaches for biodegrading and promoting the environmental biotransformation of synthetic polymeric materials)

EU FP7-KBBE-2010-4 Project ID. 266473: ULIXES (Unravelling and exploiting Mediterranean Sea microbial diversity and ecology for xenobiotics' and pollutants' clean up).

EU FP7-KBBE-2010-4 ID. 265669 Project: ECObioCAP (Efficient Biodegradable Composite Advanced Packaging).

EU FP7-2012-ID 311933 Project: WA-TER-4CROPS (Integrating bio-treated wastewater with enhanced water use efficiency to support the Green Economy in EU and India).

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BIOREMEDIATION OF CONTAMINATED MATRICES

RESEARCH GROUP: Lorenzo Bertin, Fabio Fava, Dario Frascari, Maurizio Mancini, Andrea Negroni, Massimo Nocentini, Davide Pinelli, Noura Raddadi, Giulio Zanaroli

KEYWORDS: biodegradation, biostimulation, bioreactors, microbial immobilization, modeling

The aim of the research line is to develop innovative biotechnological processes for the decontamination of soils, sediments, groundwaters and wastewaters contaminated by chlorinated and non-chlorinated hydrocarbons and by polimeric compounds. The decontamination is attained either by stimulating the indigenous microbial population of the contaminated matrix (with the possible addition of a suitable growth substrate for cometabolic processes), or by introducing in the contaminated matrix microbial populations specialized in the degradation of the target pollutants (bioaugmentation).

The main aspects of the research approach are: (1) the enrichment and selection of indigenous microbial cultures, capable to degrade the target pollutants; (2) the biochemical, physiological, kinetic and phylogenetic characterization, of the microbial cultures; (3) the design, development, optimization and scale-up of the biodegradation process; (4) the evaluation of the process through an integrated chemical, microbiological, molecular-biological and ecotoxicological monitoring; (5) the fluid-dynamic and kinetic modeling of the process, and its further optimization on the basis of the results obtained.

The main goals of the research are: (a) to develop immobilized-biomass processes in packed bed reactors, for the decontamination of ground- and waste-waters contaminated by non-ionic synthetic surfactants, polychlorinated biphenyls (PCBs), chlorobenzoic acids, phenols and chlorinated solvents; (b) to develop innovative bioreactors and advanced biodegradation strategies (use of biogenous mobilizing agents to increase pollutant bioavailability; bioaugmentation; cometabolism with pulsed feed of growth substrate) for the decontamination of soils; (c) to detect, characterize and stimulate the microbial degradation of chlorinated and non-chlorinated organic pollutants in anaerobic sediments; (d) to verify the applicability and the effectiveness of the proposed biodegradation approach to the treatment of rain waters collected from streets and industrial areas, by studying the pilot-scale application of the process in Sequencing Batch Reactors.

Fig. 1. Attached-cell bioreactor for the treatment of groundwater.

Fig. 2. Molecular analysis of the active microbial populations.
MAIN PUBLICATIONS


RESEARCH PROJECTS

EU Project FP7-KBBE-2012-3.5-02 ID 312100: BIOCLEAN (Novel biotechnological approaches for biodegrading and promoting the environmental biotransformation of synthetic polymeric materials).

EU Project EU FP7-KBBE-2012-3.5-01 ID 312139: KILL SPILL (Integrated biotechnological solutions for combating oil spills).

EU Project EU FP7-KBBE-2010-4 ID 265946: MINOTAURUS (Microorganism and enzyme Immobilization: novel techniques and approaches for upgraded remediation of underground-, wastewater and soil).

EU Project EU Project FP7-KBBE-2010-4 ID 266473: ULIXES (Unravelling and exploiting Mediterranean Sea microbial diversity and ecology for xenobiotics’ and pollutants’ clean up).

PRIN 2008: Novel processes for the sustainable remediation of groundwater contaminated by chlorinated compounds.

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WASTEWATER TREATMENT AND PLANT MANAGEMENT

RESEARCH GROUP: Maurizio Mancini
KEYWORDS: nitrogen removal, rainy conditions, finishing, monitoring, neural network, WWTP management

The research activity about URBAN WASTEWATER TREATMENT is carried out by:
- full scale investigation in Bologna WWTP about oxidization, foaming as effect filamentous biomasses and functioning during variations in dilution due to rainy weather conditions.

Results concern:
- efficiency in nitrogen removal in function of SRT and HDOC
- efficiency in primary phases with increased flow during rainy weather conditions and in oxygen dissolving in presence of filamentous biomasses.

Research activity about WASTEWATER PLANT MANAGEMENT is developed by:
- monitoring and full scale investigations in Funo (BO) SBR WWTP and in Trebbo (BO) SSR WWTP,
- continuous monitoring and laboratory scale investigations on a plant model realized in Bologna ENEA PROT laboratories.

Obtained results permit:
- identification of events and typical behaviors of signals useful in focusing variations in active biochemical processes,
- description of transitory answer obtained by orders on control plant parameters pointed out by artificial neural network.

Research activity about FINISHING, RECOVERY AND REUSE OF TREATED URBAN WASTEWATER is developed by:
- full scale investigations about finishing effect of FWS phytotreatment systems and facultative lagoons,
- laboratory experimentations about anionic/cationic/non ionic surfactants removal by magnetic filtering,
- full scale and pilot scale experiences about flow conditions and removal efficiency of O.S. and nutrients in H-SFS / V-SFS phytotreatment plants.

Results consist in discussions about:
- efficiency in disinfection and nitrogen removal of floating macrophytes and microalgal biomass,
- efficiency in surface-active substance removal,
- efficiency of finishing systems and on site treatment in order to respect existing law about wastewater recovery and reuse.
MAIN PUBLICATIONS


RESEARCH PROJECTS

DISTART-DEIS-ENEA ACS Dept.-HERA BO. Project: Authormatic Management of Municipal Wastewater Treatment.

CIRI - TECNOPOLI Project: Fluidodinamica per le applicazioni ambientali.

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SEA POLLUTION AND WASTEWATER OUTFALLS

RESEARCH GROUP: Maurizio Mancini, Renata Archetti
KEYWORDS: Oil spill, wastewater, thermoaline conditions, drifter, plume, sea currents, dispersion model

The research activity about WASTEWATER DISCHARGE IN COASTAL WATERS AND EFFECTS ON AQUATIC ECOSYSTEMS is carried out by:

• coastal dispersion modelling of freshwater coming from mouth of harbour channels and carrying out monitoring campaigns of sea water quality data. Research field are the Marano estuary mouth receiving the outfall of Riccione WWTP and Rimini Nord along-shore area, characterized by presence of coastal breakwaters near sea outlet of Marecchia river,
• monitoring campaigns of hydraulic parameters and water quality analysis executed in different tract of internal channels connected to Cesenatico port canal.

Results concern
• pointing out and calibration of a quality model describing aquatic ecosystem of transition waters in summer dry weather conditions,
• evaluation of thermoaline profile role in maintaining nutrients and pollutants in surface layers of coastal sea,
• model calibrations and prediction of freshwater dispersion plume area in summer dry weather conditions.

The research activity about OIL SPILL OFF SHORE OUTFALLS AND COASTAL ZONE POLLUTANTS DISPERSION is developed by

• testing drifter performances in tracing such offshore as coastal trajectory of floating discharged substances in different conditions of sea currents and winds,
• monitoring of freshwater discharged from Cesenatico harbour channel mouth during tidal phases and varying thermoaline conditions,
• measurements campaigns in coastal sea of vertical profiles of oxygen, temperature, salinity, pH, redox describing effects of breakwaters in conditioning freshwater alongshore distribution.

Results consist in:
• design of a proper oil spill drifter and tools to predict oil spill and validate numerical codes (GNOME, Medslik),
• validation and calibration of a 3D dispersion model, applied to a plume dispersion in low depth sea areas characterized by along-shore submerged and emerged breakwaters.

Fig. 1. Sea trajectory monitoring described by oil spill drifters. Measurement campaigns carried out in the coastal area facing Cesenatico between June and September 2009.

Fig. 2. Dispersion modelling of freshwater coming from Cesenatico Port Canal basin. Simulation of the plume dispersion during different wind and current conditions.
MAIN PUBLICATIONS


RESEARCH PROJECTS

- PRIMI: Pilot project: marine hydrocarbon pollution. Financed by Agenzia Spaziale ItalianaCIRI
- TECNOPOLI Project: Fluidodinamica per le applicazioni ambientali

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BIOFUEL PRODUCTION FROM BIOMASSES, MUNICIPAL SOLID WASTE AND SEWAGE SLUDGE

RESEARCH GROUP: Lorenzo Bertin, Fabio Fava, Dario Frascari, Alessandro Paglianti, Davide Pinelli, Noura Raddadi, Giulio Zanaroli

KEYWORDS: municipal solid waste, organic wastes, anaerobic digestion, biomethane, biohydrogen, biodiesel

The aim of this research line is to study and optimize the production of biofuels through the anaerobic digestion (AD) of organic waste (biohydrogen and biomethane) and the exploitation of lipid-rich biomasses and waste matrices (biodiesel).

The research on anaerobic digestion has the following goals: a) the study of the biomethanization of unconventional waste matrices, such as algae, municipal solid waste, activated sludge from the treatment of industrial waste, food industry waste; b) the development of chemical, physical and enzymatic pretreatments for the subsequent biomethanization of organic matrices with a high ligno-cellulosic content; c) the development of innovative bioreactors (biofilm reactors; non-conventional mixing techniques); d) the development of two-stage processes, with bioproduction of hydrogen in the 1st stage and methane in the 2nd; e) the development of prototype reactors aimed at the study and optimization of the process fluid-dynamics, using techniques such as Particle Image Velocimetry and Tomography; f) the kinetic and fluid-dynamic modeling of the process, including the use of Computational Fluid Dynamics (CFD), and its subsequent optimization. The research approach includes the biochemical, physiological, phylogenetic and kinetic characterization of the microbial cultures. A second research line aims at the optimization of the process of biodiesel production from lipid-rich seeds, algae, bacteria and organic wastes. The specific research goals are: a) the energetic optimization of the process; b) the study of innovative mixing techniques (such as static mixers), also through CFD; c) the development of innovative processes with heterogeneous and/or enzymatic catalysis; d) the optimization of the separation of biodiesel from the polar phase (glycerin and process water) through the use of coalescers; e) the biotechnological exploitation of glycerol through its conversion to 1,3-propanediol; f) the kinetic and fluid-dynamic modeling of the process.

The available equipment includes several reactors, with pH and temperature control and mechanical agitation, in the 1-30 L volume range.

![Fig. 1. Bioreactor for the biological production of hydrogen.](image1)

![Fig. 2. Bioreactors for the biomethanization of organic wastes.](image2)
MAIN PUBLICATIONS


RESEARCH PROJECTS

BIOHYDRO Project (Combined production of hydrogen and methane from agro-industrial wastes by biological processes) (2009-2013), financed by the Italian Ministry of Food and Agriculture (MIPAAF).

EXTRAVALORE Project (Valorization of the by-products of the biodiesel production process) (2010-2013), financed by the Italian Ministry of Food and Agriculture (MIPAAF).

EU Project FP7-2012-ID 311933: WATER-4CROPS (Integrating bio-treated wastewater with enhanced water use efficiency to support the Green Economy in EU and India).

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The Applied Fluid Dynamics and Mixing Group is mainly concerned with the investigation of the behaviour of equipment typically employed in the chemical and process industries. Special focus has been given to fluid mixing problems, but over the past few years attention has also been extended to fluidised beds, static mixers, membrane modules for gas mixture separations, filter-press and inertial separators for oil and gas applications.

Research efforts have been equally devoted to the development of experimental and computational techniques for the characterization and the prediction of single and multiphase flows in different process equipment. The studies in these areas are based on state-of-art experimental techniques and Computational Fluid Dynamics, on the development of mathematical and/or phenomenological models and on the application of these modelling techniques to the design, rating and optimisation of equipment.

The experimental laboratory of the research group is fully equipped for the fluid dynamic characterization of the apparatuses through two complete Particle Image Velocimetry systems (2D-PIV and Stereo-PIV), that can be used in stereoscopic configuration for the detection of the three components of the velocity fields and that can be also adopted for mixing time measurements (PLIF technique). A PIV systems has been implemented for simultaneous two-phase flow measurements and the other for bubble size and BSD determination. Recently, the investigation of dense multiphase systems based on Electrical Resistance Tomography (ERT) has been started.

For the computational activity, general purpose commercial CFD codes are usually adopted, implemented with in-house developed user functions for the introduction of specific models. As for the computer resources, several up-to-date computers are available, while on specific problems requiring particularly advanced computational resources, the supercomputing facilities of the High Performance Systems Department of CINECA have been used in the recent past.
MAIN PUBLICATIONS


RESEARCH PROJECTS

PRIN 2006: Study of the fluid dynamics of mechanically stirred reactors and tubular reactors for the production of nanoparticles or microparticles.

PRIIT 2008 (Regione Emilia Romagna): Analysis on the behavior of bi-phase fluids in filter presses.

Project EU FP6-2004-ID 019829: BIOCARD (Global Process to Improve Cynara cardunculus Exploitation for Energy Applications).

BIOHYDRO Project (Combined production of hydrogen and methane from agro-industrial wastes by biological processes) (2009-2013), financed by the Italian Ministry of Food and Agriculture (MIPAAF).


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Industrial Safety and Environmental Sustainability
Domino effect was responsible of several catastrophic accidents. Escalation of primary accidental scenarios triggering domino effect have caused extremely severe accidental events in the chemical and process industry. As a matter of facts, severe accidents may arise from the escalation of primary events to trigger secondary scenarios. Hence, the identification of possible escalation events is required in the safety assessment of sites where relevant quantities of hazardous substances are stored or handled. In the European Union, the “Seveso-II” Directive (96/82/EC) requires the assessment of on-site and off-site possible escalation scenarios in sites falling under the obligations of the Directive. The present study aims to the development of a general methodology and of support tools for the quantitative assessment of risk due to domino effect. A set of models for the calculation of equipment damage probability is developed and combined to improved criteria for the calculation of threshold values for equipment damage. A specific effort is dedicated to the improvement of models for the calculation of equipment damage probability due to jet and pool fires. In this framework, experimental studies are carried out to assess the performance of fireproofing materials used to delay the heat-up of vessels involved by fire. Experimental results are coupled to finite element models to obtain a detailed model for the prediction of time to failure. These results will be coupled to a layer of protection assessment of mitigation systems, in order to calculate the expected probability of successful mitigation with respect to the escalation scenarios. The improved vulnerability models were applied to the calculation of the contribution of escalation scenarios to the overall industrial risk due to major accident hazard. The “domino package” of the Aripar-GIS software was upgraded to allow its use for risk recomposition accounting for the contribution of domino effect. The set of tools developed allows the quantitative assessment of domino effect in complex lay-outs and extended industrial areas.
MAIN PUBLICATIONS

RESEARCH PROJECTS
ERGO Project - Value at risk of oil barrel - Convenzione Eni Exploration & Production - DICMA (2012-2014)

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ANALYSIS OF TECHNOLOGICAL ACCIDENTS TRIGGERED BY NATURAL DISASTERS (NATECH EVENTS)

RESEARCH GROUP: Valerio Cozzani, Sarah Bonvicini, Giacomo Antonioni, Amos Necci, Alessandro Tugnoli, Gigliola Spadoni

KEYWORDS: Industrial Safety, Major Accident Hazard, Natural Events, Technological Accidents, NaTech

External hazard factors as natural events and intentional acts of interference are perceived as important threats affecting the safety of chemical and process plants. The increasing frequency of some natural events having a particularly high severity also raised a growing concern for the integrity of industrial assets and for the consequences of major accident scenarios that may be triggered by intense natural events and that may lead to the release of huge quantities of hazardous substances. The specific features of technological accidents triggered by natural events were recently recognized, and these scenarios are now indicated as NaTech (Natural-Technological) accidents. The analysis of past accident databases points out that NaTech accidents frequently impacted industrial facilities. However, these scenarios are seldom considered in major accident hazard assessment, as well as in safety assessment of industrial facilities. Methodologies and tools for the specific assessment of the potential consequences of NaTech accidents were only recently developed, and are still missing for a number of specific NaTech scenarios. The present activity aims at the development of a framework for the analysis of NaTech accidents and to the advancement of tools aimed at the assessment of NaTech events.

A first aim of the activity is the development of screening criteria to apply on a regional scale, to identify hot-spots and critical sites for NaTech scenarios. A second issue is the development of models for the probability of failure of equipment items when involved in natural events. A third activity is the development of a specific methodology supported by a software tool aimed at the calculation of the individual and societal risk due to NaTech scenarios. Results obtained for case-studies evidenced that technological accidents triggered by natural events may strongly affect the overall risk due to an industrial activity.
MAIN PUBLICATIONS


RESEARCH PROJECTS


Framework agreement DICMA - EC JRC IPSC 2011-2014

Convenzione quinquennale DICMA - Agenzia Regionale di Protezione Civile Emilia-Romagna (2010-2015)

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The concentration of industrial activities close to residential areas and the related supply of hazardous materials requires operating companies and control authorities to implement adequate measures in control of major accident hazard, in appropriate land use planning, and in integrated emergency planning. The decision-making process requires the analysis of a large amount of information on risk sources, accident modeling, population distribution, etc. The treatment of such information needs the support of software tools. ARIPAR and TRAT are two software packages that implement a probabilistic methodology to the assessment of the risks of complex industrial areas, including transport of dangerous substances, producing a number of different risk indexes.

The research activities in this area mainly addressed the development of new methods, tools and models for the identification of accident scenario and their quantitative assessment. Improved methods for the identification of atypical accident scenarios are addressed within the activities of two FP7 research projects (iN-Teg-Risk and TOSCA). Specific models for the assessment of risk to the environment caused by spills of oil and/or of hazardous chemicals from pipelines were developed. More specifically, innovative risk indexes are defined for soil and groundwater and for superficial water bodies, and a well-defined procedure for their evaluation was established.

In the field of risk mitigation, operative strategies of “hazmat routing” were addressed for the transportation of hazardous substances. Hazmat routing consists in the determination of alternative paths, less risky than those usually taken by the drivers.

A further important research topic concerned fireproofing. Basic performance data for fireproofing materials were explored by experimental tests. Risk-based criteria for application to different plant areas were explored. Detailed models for the assessment of fireproofing performance were developed.
MAIN PUBLICATIONS


RESEARCH PROJECTS


Young Researchers’ Project of the University of Bologna about: “Evaluation of the environmental risk posed by pipeline transport of hazardous materials”. Project leader: Sarah Bonvicini (2000)


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From long time the occupational health and safety on workplace is matter of significant importance and evidence is given by laws that Europe has enacted. Recent developments introduced, inside laws too, risk assessment procedure and safety management systems whose specific contents were established extracting basic points by similar contexts. Necessarily the aim was and is to guarantee safe work conditions and to provide a health-observant workplace. At the same time research efforts have studied and promoted innovative methods able to evaluate models of organization for companies of any size. One of these methods was produced by using the results of a collaboration among academic and company members of different cultural background (organizational-economic, legal and medical-psychological and engineering). This method tried to achieve the balance between two important features which are: the evaluation of systems and/or patterns of health and safety organization and management in workplace, and the ability to measure effectiveness in exempting the administrative liability (as included in Legislative Decree n. 231/2001, Italian Health and Safety laws).

The introduced measures of quantification consist of two different types of tools: check-lists and indicators. These tools are based on the tree structure of the model, represented in Fig. 2. In summary values given to check-lists and indicators allow to quantify themes and key-elements and to lay the foundation of a complete score, that means obtaining the index of global performance of the examined company (IPESHE index).

A detailed evaluation of the equation representing IPESHE requires to test consistent but theoretical considerations on actual workplaces of industries. Once the procedure is well established, its use allows to define the priority of interventions for improvements, so that the management process becomes more effective and efficient.
MAIN PUBLICATIONS


RESEARCH PROJECTS

Sicurezza nell’ambiente di lavoro, Convenzione di ricerca tra la Fondazione Alma Mater dell’Università di Bologna e il Dipartimento di Ingegneria chimica, mineraria e delle tecnologie ambientali (DICMA), responsabile scientifico del DICMA: Gigliola Spadoni, 2011

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ENHANCED BIOMASS TO ENERGY CONVERSION

RESEARCH GROUP: Carlo Stramigioli, Francesco Santarelli, Lucia Basile, Alessandro Tugnoli, Valerio Cozzani

KEYWORDS: Biomass, Energy, Thermochemical processes, Supply chain analysis, Sustainability assessment

Biomass has the potential to play a significant role in the world energy scenarios due to its abundance and to the neutral contribution to the CO₂ balance when it is used as fuel.

Biomass energy content can be exploited through the direct combustion of the biomass or through the preliminary conversion of the biomass into solid, liquid and gaseous fuels followed by the combustion process. Different thermo-chemical processes can be used to produce fuels from biomass, e.g. pyrolysis, gasification, Fischer-Tropsch synthesis.

Pyrolysis is a thermo-chemical process in which organic material is decomposed in absence of oxygen in a solid residue (i.e. char), in a liquid product (i.e. pyro-oil) and in a gaseous phase. Due to the higher density of solid and liquid products, pyrolysis can be considered a densification process, which is supposed to decrease the transport burdens from the field to the final use of the bio-fuels. In particular slow pyrolysis allows for the production of similar amounts of liquid, solid and gaseous fractions. Light gases could supply the heat needed in the process.

The present activity is oriented to the analysis of biomass to energy routes based on pyrolysis processes. The experimental characterization of the pyrolysis process is carried out for different biomass species, in order to understand the yield and composition of the different product fractions, and in particular of bio-oil. Specific aspect as the thermal requirements of the pyrolysis process are also investigated.

In the perspective of bio-oil recovery, manipulation and upgrading, a further aim of the activity is the exploration of the hazard footprint of bio-oils. Finally, the sustainability of bio-energy systems based on the pyrolysis process and their compatibility with the territory still is assessed based both on reference and experimental data produced in the activity. Conventional Life Cycle Assessment (LCA) methodology as well as advanced methodologies for sustainability assessment are further developed and applied to the assessment of the biomass to energy supply and conversion chain.
 MAIN PUBLICATIONS


 RESEARCH PROJECTS


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Power generation from municipal solid waste incineration is widespread used as a technology for solid waste treatment and energy recovery. However one of the main sources of environmental impact for these plants is the continuous emission of pollutants into the atmosphere (emissions of airborne pollutants are regulated by European Union Directive 2008/1/EC on IPPC). Another issue to be addressed is the generation of solid or liquid residues from flue-gas cleaning, depending on the flue-gas treatment process.

For these reasons two-stage processes are becoming more and more popular for the treatment of the flue-gas from Municipal Solid Waste Incinerators (MSWI). Even if there are some plants that are already running this process, showing high levels of effectiveness in terms of exhaust gas concentrations, there is still lack of knowledge about reaction efficiency and reactant consumption. Thus a great amount of solid products are produced by and should be disposed of, usually by landfilling.

Among the substances produced during waste combustion, acid gases are of particular interest because of their environmental impact (long term exposure, acid rains, etc.), and a feasible solution is to remove them by means of dry processes. The two-stage dry treatment of flue gas with solid reactants is one of the Best Available Technologies for acid gas cleaning. Each stage is composed of a reactor (where the solid reactants are mixed with the flue gas) followed by a filter (where the solid products are separated).

An operational model based on literature data was proposed to describe the removal efficiency of acid gases (HCl, HF and SO2) in an incineration power plant. The model was developed considering the ratio of solid reactants (calcium hydroxide and sodium bicarbonate) to stoichiometric values, initially on the basis of plant design data. Then model parameters have been calibrated using the design data of an existing MSWI. The implementation within Aspen Hysys® allowed an economic optimization of the treatment process taking into account both reactant and disposal costs (Fig. 2).

Fig. 1. The emission stack of the MSWI running the two-stage process.

Fig. 2. Economic process optimization of the flue-gas treatment section of a MSWI.
MAIN PUBLICATIONS
Guglielmi, D., Antonioni, G., Stramigioli, C., Cozzani, V. Ottimizzazione di un processo di abbattimento a secco per l’abbattimento dei gas acidi prodotti nella termovalorizzazione di RSU. Atti Convegno GRICU 2012

RESEARCH PROJECT
Research agreement between Hera S.p.A., Alma Mater Foundation and University of Modena and Reggio e Emilia

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METHODS AND TOOLS FOR HEALTH RISK ASSESSMENT

RESEARCH GROUP: Gigliola Spadoni, Sarah Bonvicini, Giacomo Antonioni

KEYWORDS: dangerous substances effects, environmental modeling, human health, health risk evaluation, industrial and anthropic activities

The assessment of human health risk due to the use of dangerous substances in anthropic activities is a topic of growing interest for both citizens and public authorities. As a matter of fact, the former want to know the influence that such substances have on changing life conditions and the latter must establish rules and regulations to guarantee a safe exposure to them, if there is. Human health risk is assessed through a procedure based on identification, evaluation and management. As given in Fig. 1, the global evaluation procedure can be profitably conducted by using the capabilities of Geographical Information Systems able to describe the spatial distribution of sources of Chemicals of Concern (CoC), of their dispersion in air, water and soil established through fate and transport models and finally able to draw maps of cancer risk or of hazard quotient, if dangerous substances are involved, being carcinogenic or not. The research activities of the group were and are focused on all the aspects of the procedure: methodological contents, simple or complex environmental models, dose – response models of dangerous substances, uncertainties evaluation and tolerability criteria; all these topics have to be deepened if we want to give an actual and credible picture of health risks of human beings living in a territory. The software code EHHRA-GIS includes all the models previously cited; it has been built by research group step by step following innovations in fields involved, especially in modeling, and technical regulations established by national authorities. At present this tool can manipulate several sources due to industrial and civil activities or to transport, being both continuous or accidental ones (see, as an example, Fig. 2). Maps of individual risk produced by one or several substances, histograms on risk importance of substances and on the most relevant ways of intakes (by ingestion of foods, by drinking of water or different beverage...) are some of the several results which can be obtained by the code. It has to be outlined that all values are useful and important in order to support the job of territorial authorities in a correct management of risk.
MAIN PUBLICATIONS


RESEARCH PROJECT

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SAFETY AND SUSTAINABILITY DRIVERS FOR PROCESS DESIGN AND OPTIMIZATION OF SUPPLY CHAINS

RESEARCH GROUP: Alessandro Tugnoli, Valerio Cozzani, Carlo Stramigioli, Francesco Santarelli

KEYWORDS: sustainability assessment, inherent safety, life cycle assessment, optimization, key performance indicators, process & plant design, supply chain, environmental impact

The main determinants of the impact and safety of process plants are defined in the design stage, in particular in the early phases where a higher number of degrees of freedom is present. Furthermore, the production of goods causes impacts that extend beyond the actual production facility and involve up-stream and downstream processes: a holistic perspective is required in the technological optimization of such life-cycle.

The research activity on this topic focused on the development of Key Performance Indicators (KPIs), applicable as sustainability drivers in the design activities and in the supply chain optimization. The use of quantitative indicators provides auditable support in design choices and allows for selection of the production and treatment technologies which more effectively reduce environmental burdens, maximize yields and minimize costs.

The main outcomes of the research activity included:

1. Tools for the identification of sustainability KPIs through a structured approach accounting for the specific factors and constraints of design activities (e.g. limited availability of data). System analysis ranged from Life Cycle Assessment (LCA), to detailed process simulation. Experimental activity supported the collection of relevant performance data for emerging processes (e.g. biomass densification).
2. Advanced approaches for the interpretation, normalization and aggregation of indicators. The use of site-specific factors introduces a sound reference for the interpretation of the indicator values.
3. Indicators for inherent safety assessment. The methodology was developed to provide both a flexible procedure for the identification of the hazards, and a sound consequence-based quantification of the safety performance of a process scheme.
4. Specific optimization studies. Examples of studies include: alternative fuel supply chains based on biomass, production of bulk and fine chemicals, envisaged hydrogen chain for automotive applications, hazardous wastes.
MAIN PUBLICATIONS


RESEARCH PROJECTS


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In the chemical industry, a process intensification is needed to meet important goals such as sustainable and eco-friendly processes. The “produce more with less” objective can be achieved by coupling reaction and separation in a so called “integrated process”. Our research group has developed in the recent years important knowledge on the synergetic mechanisms that act in the integration of photocatalysis with membrane separation processes or other oxidative reactions. Photocatalysis is the most studied among the Advanced Oxidation Technologies (AOTs), due to many positive features: mild conditions, no chemical additives, possibility to use solar radiation to activate the reaction, modularity, simplicity for the operation and the control etc. The coupling of photocatalysis with pervaporation is simple and straightforward, even operating the two processes in separate equipments. This “membrane reactor” shows important benefits in the green synthesis of aromatic aldehydes and in water detoxification. In the first case the selectivity of the reaction is highly enhanced by the recovery by the membrane of the aldehyde while it is produced, avoiding its further oxidation in the photocatalytic reactor. The result are very satisfactory and the “AROMA” process (Advanced Recovery and Oxidation Method for Aldehydes) has been therefore patented and has been applied to the production of many aromatic aldehydes, such as vanillin and benzaldehyde. In water detoxification the membrane reactor has been used to remove recalcitrant pollutants from water streams. The rate of detoxification more than double with respect to the one obtainable without integration, thanks to a synergy between the two process. The optimization showed that a relatively low membrane area is sufficient to maximize the “intensification” index. It has been shown that also the coupling of photocatalysis with ozonization increases synergistically the rate of oxidation and the capability to control the formation of unwanted compounds. In our laboratories, many apparatuses are available for the experiments and the tests both for aqueous and gaseous effluents.

**Fig. 1.** Scheme of an integrated process in our lab.

**Fig. 2.** One of the experimental apparatuses.

**Fig. 3.** Optimization of the yield of a membrane reactor.
MAIN PUBLICATIONS


Camera-Roda et al., the “AROMA process” Patent


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Geomatics
GEODETIC ACTIVITIES IN ANTARCTICA FOR THE STUDY OF PRESENT-DAY GEODYNAMICS AND FOR THE MONITORING OF GLACIAL BODIES

RESEARCH GROUP: Luca Vittuari, Stefano Gandolfi, Antonio Zanutta, Gabriele Bitelli, Luca Poluzzi, Luca Tavaci

KEYWORDS: VLNDEF, EPICA, DOME C, TALDICE, ITASE

The geodetic activities conducted by DICAM in Antarctica within the National Program of Research in Antarctica (PNRA) concern two main areas of research: the study of current geodynamics of Northern Victoria Land and the monitoring applications of glacial bodies for studies related to paleo-climate.

The network VLNDEF (Victoria Land Network for Deformation control) consists of 28 stations located (Figure 1). Within the experiments conducted to study the geodynamics of the Northern Victoria Land were tested different GNSS analysis techniques based on the use of carrier phases (differenced and un-differenced), particularly interesting for the remote areas of the Earth.

Concerning the applications devoted to Glaciology, the research group is involved in the study of the velocity field of the ice surface for a radius of 25 km around the site of perforation depth of the Antarctic ice sheet at Dome Concordia (European Project for Ice Core in Antarctica, EPICA) through the establishment of a control network properly designed and established in situ. The whole EPICA project involved researchers of ten European nations, and it allowed to realize a deep coring in ice of about 3270 m. The extracted cores highlighted the paleo-climatic history of the last eight climatic cycles of the planet occurred in lasts 820 000 years. The scientific excellence of the whole project EPICA was rewarded by the committee of the European Science Foundation in 2007 with the prestigious Cartesio - Descartes Prize for Transnational Collaborative Research.

The group of research took part, starting from 1988, to several international projects, such as the study of the ice surface dynamics at Talos Dome, (place of a further deep ice-coring project named TALDICE) and to the International Trans-Antarctic Scientific Expedition (ITASE). ITASE is a research program promoted by the SCAR and the IGBP (International Geosphere Biosphere Programme) which involves the execution of long scientific routes realized with tracked vehicles on the Antarctic plateau.

Fig. 1. Position of the control points of the network VLNDEF, superimposed to the tectonic scheme investigated for the entire region.

Fig. 2. Tracked vehicles of ITASE project on the Antarctic plateau during the overnight stop.
MAIN PUBLICATIONS


RESEARCH PROJECTS

PNRA - RU “Geodesia e osservazioni mareografiche”. (PI G. Bitelli)

PNRA - Project: Paleoclimatic Records from Ice-core Data Elaboration (PRIDE). RU of Geodesy (PI L. Vittuari)

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Geomatics for Cultural Heritage Surveying and Cartographic Heritage

Research Group: Gabriele Bitelli, Giorgia Gatta, Fabrizio Girardi, Valentina Alena Girelli, Emanuele Mandanici, Maria Alessandra Tini, Paolo Conte, Luca Vittuari, Antonio Zanutta

Keywords: Beni Culturali, archeologia, modellazione 3D, cartografia storica

The applications of Geomatics in the field of Cultural Heritage have several purposes: study and documentation of movable or immovable objects, structural monitoring in support of restoration, integration with noninvasive diagnostic techniques (e.g. multispectral/thermal surveys), high-precision replica of works of art, creating databases for the visualization and exploration in virtual reality, new products for museums. The contextualization in the territory is done by low altitude photogrammetric surveys, large scale numerical cartography, terrestrial or aerial laser scanning, high-resolution satellite imagery.

The research of the team is oriented to the data acquisition stage, making use of integrated instrumentation (topography, digital photogrammetry, scanning systems of various types, GNSS, satellite remote sensing, GIS), and to the development and application of algorithms and techniques for optimal processing and high-fidelity 3D modeling.

Examples of activities: multi-scale and multi-technical surveys of archaeological sites, from the territory to the single object; surveying and 3D modeling of architectural complexes, painted surfaces, sculptures; high-precision topographic control of deformation for ancient buildings and infrastructures; 3D survey of small findings, high precision monitoring of decay evolution on historic outdoor brick masonry.

The group has worked in major multi-disciplinary projects in a variety of interventions: Italy, Egypt, Turkey, Albania, Syria, Malta, Uzbekistan, Tajikistan.

A particular topic, with a number of significant realizations, is the use of digital methods for the management and enhancement of historical cartography (XVI-XIX century): analysis of the genesis of the ancient map, metrical acquisition by dedicated scanners, accuracy evaluation, special methods of georeferencing, innovative visual techniques, multidisciplinary study of the map content.


Fig. 1. Image from balloon of an archaeological site; vector plotting and raster orthophoto; laser scanning and photogrammetry in the model of a dome; scanning with 3D structured light; digital processing of one eighteenth-century historical map of Bologna.
MAIN PUBLICATIONS


RESEARCH PROJECTS

PRIN2002 “Strumenti, metodologie operative e innovativi per il rilievo e la gestione dei Beni Culturali a supporto della redazione della Carta del Rischio”. Resp. Scient. G. Bitelli


PRIN2007 “Approccio multiscala per la salvaguardia di strutture archeologiche murarie in Ercolano: dal rilievo e modellazione alla diagnostica e analisi strutturale”. Resp. Scient. A. Zanutta


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The needs of monitoring structures and territory stabilities is recently often required. If the monitoring interest few isolated points the GNSS systems can be a powerful technique for their characteristics that combine high performances (at centimeter level for real time and millimeter level for long periods observation) with flexibility and costs. A first experimentation conducted by the DISTART researcher has been performed on buildings over a landslide located in the Appenines mountains. This experimentation has demonstrated the possibility to reach real time centimetre level of accuracy using low cost receiver and monitoring the position of sensors from a remote location. Now the experimentation is moving to the optimization of devices, instrumentation and software procedure in order to improve the accuracy maintaining the low cost aspect that is fundamental for a large diffusion of this method.

The final aim is to realise a monitoring system that can monitor, from remote, many structures at the same time in real time and control any movements of them. A central aspect consist in the definition of some procedure able to alert population or public authorities in case of danger. In figure 1 is reported an example of the first experimentation with the monitored buildings and obtained results. Is almost ready the realization of a real-time monitoring system for one of the most important towers of the City of Bologna both for early warning system and for the study of their low movements.

Concerning the monitoring of the territory (and in particular of landslides), Terrestrial Laser Scanner can be employed. As example a landslide in an area located over a railway has been surveyed using TLS from 2010 to 2012. All the derived products DSM and DTM obtained removing vegetation has been referred to the ETRF00 assumed as enough stable in the surveyed area. The comparison of the different surveys has evidenced the areas with movements respect the stable ones. Particularly interesting the information relative to the kinematic of landslide respect to the stable area.
PUBLICATIONS


M. Barbarella, S. Gandolfi, (2008), Monitoraggio GPS in Real Time di edifici con strumenti a basso costo., Bollettino SIFET (ISSN 1721-971X), 2008, 2, 69-86.


RESEARCH PROJECTS


PRIN2005 (2006-2007) - National Coordination. Reti di stazioni permanenti GPS per il rilievo in tempo reale in impieghi di controllo e emergenza. – Operative Unit: Reti di stazioni permanenti GNSS per il rilievo real time : configurazione in situazioni di emergenza, trasmissione dati e protocolli, inquadramento


PRIN2010-11 (2012-2014)

Operative Unit: Tecniche innovative ed emergenti di telerilevamento (da aereo, satellite, UAV) e WEBGIS per la mappatura del rischio in tempo reale e la prevenzione del danno ambientale.

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The European project EnergyCity concerns the use of airborne thermal imagery for the mapping of energy losses of buildings in seven urban areas, in the implementation of practices for energy efficiency and reduction of CO2 emissions in European cities. The final data, derived from a complex image processing workflow, are used in energy models to flow into a Decision Support WebGIS. Urban Heat Island (UHI) phenomenon is also addressed by using satellite imagery.

Environmental monitoring of a protected area in Egypt is conducted by multi- and hyper-spectral satellite images, comprising analysis of the water for Qarun Lake (salinity, chlorophyll) and lithological mapping of the area by multispectral image classification; the research furthermore covers the analysis of change detection in the region over decades, using also declassified Corona satellite imagery.

Another satellite multispectral data application is a study of the effects of salt water intrusion in the pine forests near Ravenna. The aim is to create a procedure to assess the vegetation health in areas potentially damaged analyzing NDVI. In fact, the salinization of aquifer influences the plants inducing a photosynthetic properties and coverage changes, observable by spectral measurements. From the comparison between responses in the red and infrared channels of vegetation, and its statistical validation, the most stressed areas could be identified. Subsequently, related field monitoring at detailed scale can be planned and actions carried out accordingly.

In the event of a disaster, the availability of high-resolution multispectral satellite images, along with radar data, allows to realize in a short time and with a good level of precision the mapping of large areas, for emergency management and for damage assessment in a GIS environment. Significant experiences that have been carried by the research team on various areas of the world are floods, fires, tsunamis and earthquakes, in the latter case with the possibility of obtaining a first evaluation of the level of buildings damage.
MAIN PUBLICATIONS


RESEARCH PROJECTS

COFIN2003: Tecnologie innovative per la previsione, il controllo e la mitigazione dell'impatto delle emergenze ambientali. Resp. Scient.: G. Bitelli


PRIN2008: Mapper - Procedure di acquisizione ed elaborazione di dati multisorgente per il supporto alle emergenze. Resp. Scient.: G. Bitelli


PRIN 2010-11: Tecniche geomatiche innovative ed emergenti di rilievo, telerilevamento (da aereo, satellite, uav) e webgis per la mappatura del rischio in tempo reale e la prevenzione del danno ambientale. Resp. Scient.: M. Barbarella.


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GEOMATICS FOR THE CONTROL OF GROUND SUBSIDENCE AND LONG-TERM PHENOMENA

RESEARCH GROUP: (Subsidence) Gabriele Bitelli, Luca Vittuari, Maria Alessandra Tini, Francesca Franci, Alessandro Lambertini; (Archival Photogrammetry) Antonio Zanutta, Gabriele Bitelli, Luca Vittuari, Valentina Alena Girelli, Giorgia Gatta, Andrea Lugli

KEYWORDS: Subsidence, Deformation Control, Archival Photogrammetry, Landslides, Glaciers, Laser-Scanning.

Ground subsidence (of natural type or man-induced, e.g. by fluid withdrawal) can be a critical aspect in territory management. Geometrical surveying and monitoring are the first essential steps for the knowledge and understanding of the phenomenon, to detect entity, trend and spatial arrangement of the movements. Different techniques have been applied and integrated over the years by the team: from spirit leveling (’70s) to space geodesy (the ’90s), and finally to the recent use of interferometric analysis of satellite radar images (PSInSAR). The research was carried out in national and international projects or with public authorities (Regions, Provinces, Municipalities, ARPA) and large private companies. The primary area of study is the Po Valley, with researches at regional, provincial or basin scale; a specific interest is furthermore towards coastal zones (EU FP7 project). The activity is also carried out at urban scale, monitoring single buildings and structures in city centers (e.g. Bologna) by high precision topographic techniques. The work involves the production of technical specifications, design and realization of networks, monitoring through repeated measurement campaigns, quality verification, realization of GIS databases, production of maps of subsidence rate and other related products.

Other long-term phenomena can be studied using historical data, among them old aerial photograms. The so-called Archival Photogrammetry is made today through advanced digital techniques that complement the traditional photointerpretation for: Multi-temporal landslide studies; Evolution of glaciers; Change detection in urban centers; Changes in the coastline; Changes in forest cover. For this purpose it is frequently necessary to realize Digital Terrain Models (DTM) or surface models (DSM) that allow for a metric definition of the 3D form; image matching techniques are applied on old photogrammetric images or satellite stereo-couples, and airborne or terrestrial lasercanning is an effective solution for current situations.

Fig. 1. Integration of different techniques (levelling, GNSS, radar satellite interferometry) for subsidence monitoring at different scales; map of subsidence rate for the regional Emilia-Romagna plain area, derived from radar interferometric analysis (period 1992-2000).

Fig. 2. Photogrammetric analysis of landslide movements; analysis of glacier evolution.
MAIN PUBLICATIONS


RESEARCH PROJECTS

ARPA Emilia-Romagna, su incarico della Regione Emilia-Romagna: Rilievo della subsidenza nella pianura emiliano-romagnola, Rete Regionale di monitoraggio della subsidenza (dal 1997)


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GEOMATICS FOR THE MAINTENANCE OF THE INTERNATIONAL TERRESTRIAL REFERENCE FRAMES (ITRF) AND FOR THE ANALYSIS OF NATIONAL GEODETIC NETWORKS

RESEARCH GROUP: (ITRF-Tie vectors) Luca Vittuari, Pierguido Sarti, Claudio Abbondanza, Monia Negusini, Maria Alessandra Tini (Network analysis) Maurizio Barbarella, Stefano Gandolfi, Antonio Zanutta, Luca Poluzzi, Luca Tavasci

KEYWORDS: ITRF, IERS, Tie vectors, ETRF, RND, NRTK

The realization of precise and reliable global geodetic reference frames is one of the innovations that have most contributed to the efficiency of positioning techniques, i.e. for monitoring surveys, land surveying and cadastral procedures, the stacking-out of large infrastructures, or for maritime, terrestrial and aerial navigation.

Starting from the initial applications exclusively conducted by research institutions, we can now observe a wide dissemination of the techniques of space geodesy for consumer applications, and it is sufficient to cite satellite car navigation systems or applications based on global positioning installed in smartphones or tablets PC. The reference frame more accurate is the International Terrestrial Reference Frame (ITRF) maintained by the International Earth Rotation and Reference Systems Service (IERS). The update of ITRF, entirely depends on the voluntary effort of a large number of agencies and research infrastructures, this creates a fundamental relationship between public and private, national and global technical services. This reference frame is now the backbone also for the realization of national reference frames. As example in Italy the Presidency of the Council of Ministers established by the Decree of 10 November 2011, the institution of the Rete Dinamica Nazionale (RDN) as official national reference frame, composed by 99 GNSS permanent stations. A team of DICAM studied in collaboration with the Institute of Radio Astronomy (IRA-INAF) the ensemble of high-accuracy survey methodologies and geometrical/statistical procedures necessary for the measure of eccentricity vectors between the reference points (RP) of co-located geodetic instruments and a WG was established in 2003 within the IERS - IAG Sub-Commission 1.2. Moreover DICAM is involved both in real time GNSS network for NRTK positioning and for the RDN analysis by means of the most advanced scientific GNSS data processing packages.

Fig. 1. Topographical measurements for the estimation of the tie-vectors GPS-VLBI at the IRA-INAF observatories of Medicina (BO) and Noto (SR).

Fig. 2. Residual velocities in ETRF of GNSS permanent stations belonging the Rete Dinamica Nazionale (RDN).
MAIN PUBLICATIONS


RESEARCH PROJECTS

PRIN 2007: “Uso degli osservatori geodetici co-locali VLBI-GPS per l’omogeneizzazione ed il confronto di serie storiche derivate da PS INSAR e livellazione geometrica, nello studio dei movimenti del suolo a scala regionale” (National PI A. Capra).


CISIS 2011 e 2012: Monitoraggio della Rete Dinamica Nazionale Italiana (RDN)

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QUANTUM MECHANICAL STUDY AND MODELLING OF STRUCTURAL ELECTRONIC OPTICAL AND TRANSPORT PROPERTIES OF ORGANIC SEMICONDUCTORS FOR ELECTRONIC DEVICES

RESEARCH GROUP: Renato Colle
KEYWORDS: quantum mechanics, organic semiconductors, polymers, thermoelectric materials, organic-inorganic interfaces, organic solar cells, organic field effect transistors

The aim of the research is the quantum-mechanical study, interpretation and prediction of structural, electronic, optical and transport properties of crystalline organic semiconductors, used or proposed for photovoltaic cells (OPV) and organic electronic devices, e.g. OFET. This research aims also to use the knowledge acquired on these materials to work out models useful to simulate or predict and interpret the functioning of electronic devices such as OPV and OFET. The materials considered are those of major interest for organic electronics: (1) single crystal organic semiconductors, such as perfluorobutyl dicyanoperylene diimide (PDI-FCN2) and Rubrene, that are the prototype and most efficient n-channel and p-channel materials for OFET; (2) prototype pairs of e-donor/e-acceptor crystalline organic materials for "Bulk Heterojunction" (BHJ) solar cells, such as P3HT(polymer) / PCBM (fullerene derivative); (3) ionic liquid crystalline materials, such as dicationic thienoviologen salts of different alkyl-chain lengths, that self-assemble into either calamitic or columnar mesophases and are used in the new interdigitated BHJ OPV. In the study of these materials, large attention is also devoted to the structure and properties of interfaces, such as e-donor/e-acceptor, organic semiconductor/metallic electrode or insulating substrate. Finally, (4) we study also organic materials, such as semiconducting conjugated polymers, e.g. polyanilines, polypirroles, polythiophenes, that seem to be the best candidates, alternative to inorganics, for the realization of economic and efficient thermoelectric materials, being characterized by poor thermal conductivity, but good electronic conductivity if suitably doped.

Some of the indicated activities are carried out in collaboration with research groups of the Department of Physics, University of Pisa (activities 1, 2, 4) and of the Department of Chemistry, University of Calabria (activity 3).
MAIN PUBLICATIONS


POLYMERIC COMPOSITES AND NANOCOMPOSITES FOR ADVANCED APPLICATIONS

RESEARCH GROUP: Andrea Munari, Maurizio Fiorini, Nadia Lotti, Annamaria Celli, Martino Colonna, Lara Finelli, Laura Sisti, Paola Marchese, Francesco Di Credico, Matteo Gigli, Matteo Moncalero, Marco Nicotra, Grazia Totaro, Micaela Vannini

KEYWORDS: layered silicates, layered double hydroxide, carbon nanotubes, fullerenes, biofibres

The skills developed by the research group in the field of polymeric composites and nanocomposites arise from the specific needs for high-performance materials, characterized by low environmental impact. The applications of these materials are wide: in fact, depending on the type of nanofiller employed, they are characterized by high mechanical performance, heat resistance, reduced gas permeability and flammability and by specific properties, such as conduction, optical, antibacterial and photo-catalytic properties. In all cases, in order to obtain the best possible performances of the final material, physicochemical properties of the inorganic phase, such as surface area, morphology, particle size, interaction with the polymer chains and their functional groups, are developed. Moreover, the degree of dispersion and adhesion at the interface with the matrix, which play a crucial role and can be controlled by acting on the chemical modification of fillers and on the techniques used for their mixing with the matrix, are also improved. The research group is able to synthesize, for the specific needs, inorganic fillers compatible with polymer matrices and to disperse them by direct polymerization or by melt mixing using Brabender or co-rotating twin-screw extruders. Moreover, in the field of composite, research has been focused on the preparation of materials based on poly (butylene succinate) (PBS), which constitutes one of the emerging biopolymers. Currently the application of this polyester is limited due to the high production costs and reduced mechanical and gas barrier properties. To solve these issues composites with lignocellulosic fibers, such as those derived from coconut, sugarcane bagasse, curauá and sisal, have been prepared through the technique of thermoforming. Excellent results in terms of adhesion at the interface and mechanical properties were obtained without chemically altering the fibers and then developing a final material completely “bio”.
MAIN PUBLICATIONS


PATENTS


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In the last years the polymer group of the DICAM has focused his attention towards the study of advanced polymeric materials for sport equipment, in particular for winter sports, e.g. ski boots. Hitherto, both in academia and in industry, the research in this field has been minor. Our method is based on a scientific approach to choose and develop new materials with specific characteristics such as low weight, good visco-elastic properties, high impact resistance at low temperatures and gliding on snow. Thanks to our knowledge in the characterization and synthesis of polymeric materials we are able to use a new technique to evaluate and select appropriate materials for the different applications. For example, through DMTA analysis we can evaluate the optimal parameters of the visco-elastic material’s behavior. By analyzing the variation of the elastic modulus with temperature it is possible to evaluate the stiffening of the material in the different conditions of use. From the loss modulus ($E''$) it is possible to deduce the vibration’s damping of the material and the speed of elastic return once the stress is finished. These parameters have a fundamental effect on the final performance of the sports equipment. The correct choice of material also helps in product design, providing higher performance and less weight. Moreover, the DMTA analysis allows to calculate the temperature at which the material softens. This fact may be used to modify the equipment’s geometry through a thermoforming process that allows the customization of the product on the needs of the final user. Using our expertise in materials obtained from renewable sources, we can define the most appropriate materials, reducing the carbon footprint of the product. We are also equipped with wireless sensors that can measure on field the thermal comfort and moisture transport during the use of materials, equipment and technical sports clothing.
MAIN PUBLICATIONS
Colonna M., Fiorini M., Nicotra M. and Moncalero M. Viscoelastic properties of thermoplastic materials used for ski boots. *ISEA 2012 International Meeting, Lowell USA.*

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As it is well known, polymers are the most versatile class of materials, thus can be favorably designed to fulfill the needs related to the variety of tissues and diseases involved in the human body. The research group has recently focused its activities on three main aspects of biomedical engineering: tissue engineering, controlled drug release and polymers with antibacterial properties.

**Tissue engineering** The control of molecular structure and tridimensional architecture of synthetic polymeric constructs (scaffolds) – designed to reproduce the typical properties of the damage tissue – is a key element for controlling cell adhesion, proliferation, migration and differentiation. In the field of tissue engineering the possibility to employ scaffolds mimicking native tissue is limited by the scarce availability of biocompatible and biodegradable polymers with proper mechanical properties, especially in terms of stiffness.

**Controlled drug release** Classical methods of drug delivery exhibit specific problems that scientists are attempting to address. The goal of new drug delivery systems, therefore, is to deliver medications intact to specifically targeted parts of the body and to release them in a controlled way depending on the required treatment regime. The design of the drug carrier is fundamental in order to achieve the correct tissutal and cellular localization of drug molecules and perform an adequate release. In this framework, polymers and copolymers are the most promising tool to obtain materials showing specifically designed properties to be employed as drug carriers.

**Polymers with antibacterial properties** Antibacterial properties can be introduced into a polymer by following different strategies: chemical modifications carried out in bulk, surface modification, blending with chemically modified nanofillers.
MAIN PUBLICATIONS


RESEARCH PROJECTS
PRIN NANOMED. Molecular Nanotechnologies for controlled drug release.

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MONOMERS AND POLYMERS FROM BIOMASS AND FROM WASTE OF AGRO-FOOD INDUSTRIES

RESEARCH GROUP: Andrea Munari, Maurizio Fiorini, Nadia Lotti, Annamaria Celli, Martino Colonna, Lara Finelli, Laura Sisti, Paola Marchese, Claudio Gioia, Grazia Totaro, Micaela Vannini

KEYWORDS: bio-based monomers, biopolymers, bio-PET

There is today a clearly detectable increasing interest in exploitation of non-food biomass and industrial wastes. Moreover, academic and industrial research is interested in the preparation of bio-based polymers, i.e. polymers obtained from renewable resources, in order to substitute the traditional petro-based polymers.

By the combination of these two necessities, we have developed some research activities which are focused on the exploitation of biomass and agro-food wastes to prepare bifunctional monomers, mainly for the polyester synthesis.

An example of such activity is the development of a chemical route which starts from terpenes (in particular, from limonene, which is a raw material of juice industry) to prepare terephthalic acid (TPA) and derivatives (see Fig. 1). TPA is an important monomer, from which poly(ethylene terephthalate) (PET) and poly(butylene terephthalate) (PBT), some of the most important commercial polymers, are produced. For the first time, it was possible to prepare fully biobased PET and PBT. Moreover, other polymers, prepared starting from TPA derivatives, are now potentially fully biobased materials. This is the case of aliphatic polymers containing 1,4-cyclohexylene units, for example poly(1,4-cyclohexylenedimethylene-1,4-cyclohexanedicarboxylate) (PCCD) polymers, which are used for outdoor applications, due to their high UV resistance.

Our research group is developing analogous approaches to obtain other bio-based dicarboxylic acids, diesters, diols starting from non-food biomass and wastes.

Fig. 1. Synthesis of bio-PET and bio-PBT.
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This research field is mainly focused on the synthesis and characterization of novel biodegradable polymers and copolymers which offer physicochemical properties suitable for the desired application. An alternative approach consists in the chemical modification of commercially available polymers to make them attractive for different uses.

Regardless of the synthetic approach adopted, the main goal is to find out structure-properties relationships of main interest for designing a material which completely fits the requested specifications. As an example, green food packaging materials must accomplish basic requirements to be an ideal candidate for food, which includes barrier properties (water vapor, gases, light and aroma), optical properties (transparency), strength, welding and molding properties, disposal requirements, antistatic properties and, above all, strictly follow food safety.

Copolymerization as well as physical and/or reactive blending approach are an effective way of achieving a deliverable combination of properties, which are often absent in single component polymers. Moreover, the final properties of the material can be favorably modified, depending on the kind, relative amount, distribution and architecture of the comonomeric units or, in the case of mixture, by properly varying the homopolymers and blend composition. The choice of the monomers to be used in the polymerization process as well as of the comonomeric unit to be introduced along the polymeric chain of the parent homopolymer will be made on the basis of the requirements that the materials have to satisfy.

The so synthesized polymers are fully and deeply characterized both using the technology available in the DICAM labs and through collaborations with other research groups.
MAIN PUBLICATIONS


RESEARCH PROJECTS

EU FP7-KBBE-2012.3.5-02 Project: BIO-CLEAN. New biotechnological approaches for biodegrading and promoting the environmental biotransformation of synthetic polymeric materials.

PON NAMASTE. Nanomaterials for sustainable building.

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INVESTIGATION OF POLYMER CRYSTALLIZATION PROCESS

RESEARCH GROUP: Andrea Munari, Maurizio Fiorini, Nadia Lotti, Annamaria Celli, Martino Colonna, Lara Finelli, Laura Sisti, Paola Marchese, Matteo Gigli, Grazia Totaro, Micaela Vannini

KEYWORDS: crystallization kinetics, melting behavior, morphology, structure-property relationship

It is well known that crystallization is a phase transition that plays an important role in determining the morphology of a polymer for a wide range of technological processes. Therefore, studies of the isothermal crystallization of polymers commonly have been used to investigate the specific mechanisms of the crystallization process and from a technical standpoint are relevant to optimizing process conditions. In fact, the morphological structure (size, shape, perfection, orientation of crystallites), which is formed by crystallization from the molten state, influences strongly most of the physical and mechanical properties of polymeric products. Moreover, because the crystal structure and morphology (the crystal habit and organization of crystals into aggregates of a higher order) are responsible for many properties of the final products, knowledge of the crystallization mechanism is crucial for designing materials with the required properties. The crystallization kinetics are investigated by DSC and hot-stage optical microscopy (MO), both available at the laboratories of the Department. MO technique, beside measuring spherulitic growth rate, allows to obtain information on crystal phase morphology, which changes with undercooling degree and therefore with Tc. Both melt isothermal and non-isothermal crystallization kinetics studies are carried out. Melt isothermal crystallization kinetics is investigated by DSC technique and the data analyzed according to the Avrami’s treatment. The data obtained from measurements carried out under non-isothermal conditions are analyzed according Tobin and Ozawa equations. The crystallization process is also investigated employing equipments located at other research laboratories, such as: XRD, AFM and DETA. Lastly, structure-property relationships, which are fundamental to design a new material with “ad hoc” properties, are found. For copolymers, crystallization parameters are correlated with copolymer composition (random copolymers) and with molecular architecture, i.e. crystallisable block length (block copolymers).

Fig. 1. Crystallization rate of homopolymers and copolymers, determined in isothermal conditions, as a function of the undercooling degree.

Fig. 2. Optical micrographs of PGA homopolymer, isothermally crystallized at 145°C.
MAIN PUBLICATIONS


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SUSTAINABLE CONCRETE, RECYCLING AND ENVIRONMENT

RESEARCH GROUP: Maria Chiara Bignozzi, Elisa Franzoni, Stefania Manzi, Andrea Saccani

KEYWORDS: industrial waste, waste, eco-cements, durability

With the aim to obtain materials with high durability and good performances for civil engineering, the research is focused on the mix-design and characterization of sustainable concrete (i.e. concrete with eco-cements, sulphur concrete, concrete where natural aggregates are replaced with construction and demolition waste and/or end-use tyre rubber, etc.). Innovative and sustainable conglomerates are designed combining high durability features with the introduction of waste materials in the mix design. Mix-design, physical and mechanical properties, microstructure, alkali-silica reaction (ASR), durability in aggressive environment, and protection against corrosion are studied to design conglomerates with tailored properties. Porosity and its distribution are deeply investigated by means of mercury intrusion porosimetry and microscopy techniques. Tailoring the porosity through the optimization of conglomerate mix-design, allows tuning the mechanical properties and the density of the final product.

The research on recycling of waste and by-products for the development of new building materials is often supported by different industrial partners. Recycling contributes to the valorisation of waste and reduction of environmental impact, thus avoiding waste landfill disposal and use of non-renewable resources. The treatment and use of waste from construction and demolition, the recycling of waste wash water coming from ready-mix concrete plants, of ceramic industry by-products, of end-used tyre, of glass waste from separate collection, of ashes from incineration of municipal solid waste, of poly-meric and agricultural waste, etc. are studied. These by-products are successfully used as new constituents for ecocements, fiber reinforcement, aggregates and filler for ordinary and self-compacting concrete. In the field of materials for architecture, new methodologies have been set up. They concern the evaluation of construction materials sustainability and new systems of integrated design for the reduction of environmental impact related to the construction and building service life (energy saving, renewable energy sources available on-site, etc.).
MAIN PUBLICATIONS


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ALKALI ACTIVATED MATERIALS (GEOPOLYMERS) FOR CONSTRUCTIONS
RESEARCH GROUP: Maria Chiara Bignozzi, Stefania Manzi
KEYWORDS: inorganic polymers, physical-mechanical properties, microstructure, durability

Alkali activated materials (AAM) are a new class of inorganic materials obtained by calcium-alumino-silicates precursors. Such precursors are able to consolidate when treated with strong alkaline solutions at temperatures between 20°C and 100°C. If the nature of the starting materials is mainly alumino-silicate (i.e. metakaolin coming from calcined caolin), then the relevant activated materials are known as ‘geopolymers’. The interest for this new class of materials is based on several factors: (i) industrial waste can be used as precursors thus saving natural raw materials; (ii) alkali activation is a productive process with a low environmental impact if compared with the industrial processes of traditional building materials; (iii) alkali activated materials can be used as binders (similarly to cement) to produce composites and conglomerates or as one-phase materials to obtain blocks and tiles also suitable for high temperature applications.

The research activity is mainly focused on innovative precursors in order to: (i) set up their mix design and process parameters (time, temperature, types and concentration of alkaline solutions, molar ratios, etc.); (ii) provide fresh state characterizations and optimize moulding technology; (iii) provide physical-mechanical characterization of the final products at the hardened state (with special focus on porosity and its control); (iv) study their physical and mechanical behaviour after high temperature treatments; (v) investigate final products durability by means of climate chambers with temperature, humidity and ultraviolet controls.

The research activity is carried out in collaboration with the Department of Engineering “Enzo Ferrari”, University of Modena (Prof. Cristina Leonelli) and the Centre for Materials Research, Curtin University, Perth, Australia (Prof. A. van Riessen).
MAIN PUBLICATIONS


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The research activities in this field range from diagnostic investigations on ancient buildings, to the evaluation of compatibility and durability of conservation materials, to the design and set-up of new restoration materials (with their application techniques). New diagnostic techniques and protocols based on a holistic approach have been developed, as a tool for the restoration of ancient building materials. The Research Unit has been involved in the diagnostic investigations on several Italian and European historic buildings, e.g. Tiberius bridge in Rimini (I cent.), St. Mark basilica in Venice (XI cent.), Montetiffi abbey, RN (XI cent.), Pio Palace at Carpi (XV cent.), St. Francis church at Correggio (XV cent.), Ducal Palace in Mantua (XVI cent.), S. Caterina degli Italiani and Sarria churches in Malta (XVII cent.), Vizzani Palace in Bologna (XVI cent.), St. Luca porticoes in Bologna (XVII cent.), Isolani Palace in Bologna (XVII cent.), Casa Major Pessoa in Aveiro, Portugal (XX cent.) and other Art Nouveau buildings in Italy.

An important research line concerns the problem of measurement and reclaim of rising damp in ancient brick and stone masonries (by means of on-site and laboratory experimental campaigns), as well as the relevant electrokinetic effects and the decay effects. Research on materials involves several key aspects for the architectural restoration design, also in collaboration with foreign colleagues (e.g. EMPA, Princeton University, Universidade de Aveiro) and industrial partners: materials durability in aggressive environments, historic building materials, set-up of innovative and compatible conservation materials. The development of innovative materials includes: new consolidants based on hydroxyapatite, silicate consolidants, nanoconsolidants, self-cleaning photocatalytic finishing for façades.

The Unit is member of the “Integrated Research Team - Alma HeritageScience” (University of Bologna) in the field of heritage conservation. Collaborations are currently running with several Italian Superintendences, Municipalities and local Administrations.
MAIN PUBLICATIONS


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INDUSTRIAL AND ADVANCED CERAMIC MATERIALS

RESEARCH GROUP: Alberto Fregni, Giorgio Timellini

KEYWORDS: innovative ceramic materials, functionalized ceramic surfaces, environment, ceramic industry

The aim of the research activities is design and development of innovative ceramic materials, characterization and verification of performance characteristics, optimization of production processes, solving of environmental and process problems in the ceramic industry.

In the field of traditional and advanced ceramic materials, research activity concerns mainly:

- qualification and testing of the performance characteristics of traditional ceramic materials, according to operating conditions and target environment and application techniques;
- optimization of production processes of traditional ceramic materials, experimenting with innovative technologies that improve the quality of the product;
- environmental problems in the ceramics industry (pollution, energy consumption, waste disposal/recycling of products, etc.);
- design of innovative construction materials with high thermal and acoustic performances;
- functionalization of ceramic materials: high solar reflectance, photovoltaic, photocatalytic, antibacterial, antiwear surfaces;
- study of shaping techniques to obtain innovative ceramics (bioceramics and piezoelectrics).

Fig. 1. EM-EDS mapping of titania particles on ceramic substrate: dip coated sample (20x60mm) after firing.

Fig. 2. 3D image of a screen printed Ag layer.
MAIN PUBLICATIONS


RESEARCH PROJECTS

Progetto RFO (EX 60%) E.F. 2009 – Comitato 09 – Ingegneria Industriale e dell’Informazione; Coordinatore del gruppo di ricerca Prof. Ing. Giorgio Timellini.

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POLYMERS AND ADVANCED COMPOSITE MATERIALS
RESEARCH GROUP: Maria Chiara Bignozzi, Stefania Manzi, Antonio Motori, Andrea Saccani
KEYWORDS: particle and fibre reinforced composites, polymer and ceramic matrices

Research activity is mainly focused on polymeric materials, micro or nano-sized composite materials, fiber reinforced composites with ceramic or polymeric matrix, toughened materials. As reinforcement natural fibers as straw and hemp are also investigated. Mechanical, microstructural and thermal characterization of traditional and innovative polymeric materials is performed. Special focus is addressed to investigate the relationship occurring between microstructure and macroscopical properties of the polymer. Laboratory techniques allow to investigate the crystallinity, the orientation and distribution as well as the relative amount of the different phases. An important aspect is related to the study of polymer degradation in specific and tailored environmental conditions (oxygen, temperature, UV radiation, relative humidity, body fluids). The life-time of the polymer is evaluated through the choice of suitable diagnostic properties. The effect of organic-inorganic coatings on the durability of substrates is also studied. Particular interest is addressed to polymers used as high voltage electrical insulating materials, for automotive, biomedical and civil engineering applications.

As to what concerns composite materials, we investigate: the toughening of ceramic or polymer matrix respectively by fibers and by a second elastomeric phase or graphene platelets, the use of natural fibers (hemp or straw) in hybrid organic-inorganic matrices.

Fig. 1. Fibre reinforced composite material.

Fig. 2. Toughened ceramic material.
MAIN PUBLICATIONS


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CORROSION AND PROTECTION OF METALS

RESEARCH GROUP: Maria Chiara Bignozzi, Stefania Manzi, Antonio Motori

KEYWORDS: corrosion, accelerating ageing, electrochemical measurements, surface characterization

The aim of the research is the development of guidelines for the prevention and protection from corrosion of ferrous and non-ferrous alloys exposed to different environments. Research projects concern the study of corrosion mechanisms and protection of metal alloys used in the industrial sector (i.e. “Corrosion of 316L in Ultrahigh-Purity Water for Pharmaceutical Industries” and “Corrosion of different steels in Chemical Plants”), in Cultural Heritage (i.e. “Corrosion behaviour and protection of outdoor bronzes”) and in architecture/building construction (i.e. “Atmospheric corrosion of COR-TEN steel with different surface finish” and “Corrosion of steel bar reinforcement in geopolymer or cement matrix”). In particular, the evaluation of the corrosion behaviour and the protective efficiency of coatings is performed through accelerated ageing, surface analyses, thermal analyses, electrochemical measurements. Research activities are carried out in collaboration with research groups of the Interdepartmental Center for Industrial Research of the University of Bologna for Advanced Applications in Mechanical Engineering and Materials Technology CIRI-MAM (Corrosion Unit: Dr. Cristina Chiavari), of the Industrial Engineering (Dr. Carla Martini) and Industrial Chemistry «Toso Montanari» (Dr. Elena Bernardi) Departments of the University of Bologna, of the Corrosion Center “Daccò”, University of Ferrara (Prof. Cecilia Monticelli). Moreover, research projects supported by national and international companies are developed in order to solve technological problems due to unexpected corrosion phenomena.

Fig. 1. Electrochemical cell with thermostat.

Fig. 2 Polarisation curves.

Fig. 3 Corten structure in Cemetery of Certosa (Bologna, Italy).
MAIN PUBLICATIONS


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ELECTRICAL BEHAVIOUR, AGING AND RELIABILITY OF POLYMER-BASED INSULATING MATERIALS

RESEARCH GROUP: Antonio Motori, Andrea Saccani
KEYWORDS: polymeric insulating materials, nanocomposites, aging, dielectric losses

The investigation of the electrical properties studies allow to make correlations with the physical, mechanical, structural and microstructural characteristics of materials.

In the laboratory, the electrical bulk and surface conductivity are investigated in the temperature range from -80 to 250 °C, as well as the permittivity and the loss factor from $10^{-2}$ to $10^6$ Hz.

Main research topics are insulating materials and polymeric systems, including nanocomposites.

The more relevant aims are:

1. the investigation of the aging mechanisms of insulating materials and the evaluation of the time behaviour and reliability through accelerated test methods that simulate the on-service conditions;

2. the investigation of the conduction mechanisms and of the dielectric relaxation processes in the bulk and at the interfaces.

3. the deposition of organic-inorganic coatings with peculiar properties (antistatic, charge injection barrier).

Some of the indicated activities are carried out in collaboration with research groups of the University in particular with the Department of Electrical Engineering “G. Marconi” of the University of Bologna.

Fig. 1. Laboratory of electrical measurements.

Fig. 2. Cell for accelerated aging.
MAIN PUBLICATIONS


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Structures
DEFINITION OF INPUT GROUND-MOTIONS FOR NONLINEAR DYNAMIC ANALYSIS

RESEARCH GROUP: Nicola Buratti, Giada Gasparini, Marco Savoia, Stefano Silvestri, Tomaso Trombetti

KEYWORDS: earthquake engineering, accelerograms, intensity measures, nonlinear dynamic analysis, seismic hazard

In the framework of performance based earthquake engineering, the assessment of the seismic structural demands is extremely important. This latter, is usually defined through a sequence of nonlinear dynamic analyses that require to define some sets of accelerograms as input. The choice of the accelerograms is crucial for the correct prediction of the structural response. The research carried out covered different aspects of this issue. The research group developed a new probabilistic seismic hazard analysis (PSHA) procedure that leads to the definition of the probability function (PDF and CDF) of the various intensities of the ground-motion. Using this results the group developed a new vector ground-motion intensity measure based on the combination of PGA and PGV. Finally the research group studied the features (in terms of spectral acceleration) that a set of accelerograms must present in order to be associated to a given probability of occurrence, and hence proposed a new procedure for defining sets of design ground motions.

The research group also developed a procedure for simulating non-stationary stochastic accelerograms, using ground-motion prediction equations to obtain realistic estimates of some important ground motion intensity measures: duration, Arias intensity, and frequency content. The so generated accelerograms were used as input for nonlinear dynamic analyses of various RC structures and gave results that compared very well with those obtained from recorded accelerograms.

Finally, as a results of a collaboration with Imperial College, London, we developed a new criterion to select and scale recorded accelerograms starting from the definition of a scenario in terms of magnitude and source-to-site distance. The procedure is based on the definition of a target response spectra, using the data provided by spectral-acceleration attenuation relationships. This method has given good results both in terms of estimates of the mean structural response and in terms of its distribution.
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ADVANCED PROCEDURES FOR THE ASSESSMENT OF SEISMIC RELIABILITY

RESEARCH GROUP: Nicola Buratti, Pier Paolo Diotallevi, Barbara Ferracuti, Luca Landi, Marco Savoia

KEYWORDS: seismic risk, seismic fragility, reliability, probabilistic methods, earthquake engineering, SAC/FEMA

In the framework of Performance-Based Earthquake Engineering the actual research trend is to develop rigorous probabilistic approaches. These latter involve complex nonlinear problems with many random and non-random variables. For this reason many practical reliability methods have been recently developed for assessing seismic safety. The main purpose of this research concerns two of these approaches: the “2000 SAC/FEMA Method” and response-surface based methods. As for the 2000 SAC/FEMA Methods, used for the reliability analysis of different R.C. frames, also equipped with dampers, on a first stage, probabilistic hazard analyses were performed for several sites in Italy, and then the Probabilistic Seismic Demand was defined through Incremental Dynamic Analyses (IDA), considering both flexure and shear failure modes. Particular care was put into the study of the sensitivity of the results to the ground-motion intensity measure used. This issue was further investigated during a collaboration with the “Blume Earthquake Engineering Center” at Stanford University, that lead to the proposal to a new intensity measure.

The second procedure investigated is based on the response-surfaces with random factors. These statistical models are used for approximating the structural capacity, in terms of spectral acceleration, through a polynomial function of the variables considered. The coefficients of the polynomial are fitted using data gathered from a set of non-linear incremental dynamic analysis. The number of simulations required increases as the number of variables increases, therefore in order to keep the model computationally efficient the aleatory variables involved can be split in two groups: one in taken into account explicitly in the polynomial while the second is considered only implicitly, by dividing the numerical simulations in blocks and introducing random factors in the polynomial model. Recently the research group has also started to investigate the seismic vulnerability of cylindrical tanks containing liquids.

Fig. 1. IDA curves calibrated for a given seismic intensity measure.

Fig. 2. Fragility curves obtained from response surface models.

Fig. 3. Fragility curves for cylindrical tanks.
MAIN PUBLICATIONS


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PROBABILISTIC APPROACHES IN STRUCTURAL ENGINEERING

RESEARCH GROUP: Stefano de Miranda, Cristina Gentilini, Lucio Nobile, Francesco Ubertini, Erasmo Viola

KEYWORDS: probabilistic analysis, identification techniques, Bayesian approach, uncertainty, random fields

This research topic encompasses the development of numerical simulations for the probabilistic analysis of structures and components.

In particular, the research focuses on:

(1) probabilistic analysis of structures with uncertain damage. Crack depth and location are modeled as random variables in order to take into account the unavoidable uncertainty that always affects damaged structures. A simple and accurate method for the probabilistic characterization of the linear elastic response of cracked structures with uncertain damage is employed. According to this method, the uncertainties are transformed into superimposed deformations depending on the distribution of internal forces and an iterative procedure is established to solve the resultant equations;

(2) dynamic identification of elastic constants of thick laminated composite plates. The plate response is modeled by finite elements based on Reddy’s third-order theory. The elastic constants are estimated within a Bayesian framework, using two estimators available in the literature. The estimators differ in the way they account for a priori information on the elastic constants to be identified. A modified strategy is proposed that overcomes the drawbacks of the literature estimators;

(3) identification of damaged elements by means of Genetic Algorithms. The objective is to evaluate the mechanical characteristics of constituent bars in existing truss structures. In particular, the proposed procedure locates bars with reduced mechanical properties and quantifies the loss of stiffness. The procedure is based on genetic algorithms to overcome lack of information;

(4) numerical procedures for random field simulation in mechanics.

Fig. 1. Cracked element – displacement distribution.

Fig. 2. Cracked frame structure with uncertain damage.

Fig. 3. Thick composite laminated plate.
MAIN PUBLICATIONS

RESEARCH PROJECTS

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MULTIPHYSICS AND COUPLED PROBLEMS

RESEARCH GROUP: Giovanni Castellazzi, Stefano de Miranda, Luisa Molari, Francesco Ubertini, Erasmo Viola

KEYWORDS: fluid-structure interaction, coupled deformation-diffusion, phase transitions, salt attack, piezoelectricity

This research line encompasses the development of ad-hoc numerical formulations for the analysis of several coupled problems.

In particular, tools are developed for:

- CFD simulation of high Reynolds number flows around stationary and moving bluff bodies aimed at predicting aerodynamic and aeroelastic forces. The flutter critical speed is evaluated before wind tunnel tests allowing optimal deck design;

- simulation of phase transition in metals provoked by heat treatments, largely employed in the industrial applications, which involves a microstructural transformation;

- simulation of fluid-structure interaction problems by coupling the lattice Boltzmann fluid solver and the finite element solid solver. A proper coupling strategy has been developed. A wide range of applications has been investigated, spanning mechanics, industry/defence, biology and biomimetics;

- simulation of the mechanically driven mass diffusion in deformable solids, aimed at predicting the so-called hydrogen embrittlement, which may occur in metals containing an initially uniform dilute concentration of hydrogen;

- simulation of the masonry degradation due to the salt attack.

- modelling of crack growth in piezoelectric materials.

Fig. 1. Unsteady RANS simulation around Gibraltar bridge deck section: vorticity contours.

Fig. 2. Simulation of diffusive and displacive phase transitions.

Fig. 3. Simulation of the take-off of two butterflies: velocity field.
MAIN PUBLICATIONS


RESEARCH PROJECTS


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NUMERICAL METHODS FOR STRUCTURAL ANALYSIS

RESEARCH GROUP: Giovanni Castellazzi, Stefano de Miranda, Elena Ferretti, Cristina Gentilini, Alessandro Marzani, Luisa Molari, Lucio Nobile, Francesco Tornabene, Francesco Ubertini, Erasmo Viola

KEYWORDS: finite element method, time integration methods, structural dynamics, meshless method, error estimation

This research line encompasses the development and application of new and effective numerical methods and computational techniques for the solution of structural engineering problems.

The current research activities address a wide range of structural issues, including:

- finite element formulations for arches, plates and shells,
- stress recovery techniques in finite element analysis,
- a posteriori error estimation in finite element analysis,
- time integration methods for transient analyses,
- finite element approaches for structural dynamics,
- discontinuous Galerkin methods,
- flexible multi-body systems,
- finite element formulations for the dynamic analysis of damaged structures,
- meshless methods for the analysis of vibrations of spherical and parabolic shells,
- nonconservative stability problems,
- finite element and boundary element formulations for modeling bulk, guided and leaky guided waves in solids,
- cell method formulations for crack paths analysis in brittle materials,
- special finite elements for stress concentration problems,
- image-based finite element modelling.

Fig. 1. RCP stress recovery and adaptive mesh refinement.

Fig. 2. From magnetic resonance to finite element modelling.

Fig. 3. Mode shapes of different shell structures.
MAIN PUBLICATIONS


RESEARCH PROJECTS

EU FP7-AAT-2011-RTD-1 ID. 284562 Project: SARISTU. Smart Intelligent Aircraft Structures.

Verification in computational structural mechanics, PRIN2007 – Research Unit of Bologna, coordinator: Prof. F. Ubertini.

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ADVANCED COMPUTATIONAL TOOLS FOR ANALYSIS AND DESIGN OF REAL STRUCTURES

RESEARCH GROUP: Giovanni Castellazzi, Stefano de Miranda, Cristina Gentilini, Alessandro Marzani, Luisa Molari, Francesco Ubertini

KEYWORDS: steel structures, falling rock protection barriers, leakage in cracked pipes, ceramic sanitary ware, guided waves

This research line encompasses the application of advanced computational tools for the analysis and design of real structures. The current research activities address a wide range of issues, including:

- linear and nonlinear structural analysis of thin walled beams, with emphasis for cold-formed steel members, in which local phenomena such as section distortion require the use of beam models with enriched kinematics or three-dimensional shell models,
- numerical strategies for the design and verification of flexible falling rock barriers: passive protection measures for risk mitigation of potentially unstable rock slopes. The key point of the proposed approaches is that notwithstanding the complexity of the simulated phenomenon, the resulting highly non-linear, dynamic models are simple and produce an accurate prediction of all the relevant parameters for barrier design, such as anchorage forces, net panel elongations and residual heights,
- modelling of ceramic sanitary ware deformations during the production process,
- analysis of the effects of permanent ground deformation on underground and above ground pipe networks,
- analysis of waveguides dispersive properties,
- models to evaluate the influence of the deformability of a cracked pressurized pipe on leakage, with a focus on losses because of longitudinal splits. The purpose is to evaluate the opening area (leak area), while keeping the model as simple as possible,
- nonlinear analysis of masonry structures,
- modelling of tiles debonding due to shrinkage: substrate shrinkage or temperature variations can produce differential elongation/shortening between tiles and substrate. Consequently the tiling failure like mode I mechanism can occur.

These issues have advanced broad applications in the engineering practice of modern structural analysis, design and construction of buildings and other structures.
MAIN PUBLICATIONS


RESEARCH PROJECTS

Models and algorithms for the nonlinear analysis of structures and performance-based design, PRIN2010 – Research Unit of Bologna, coordinator: Prof. F. Ubertini.

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**MATERIALS CHARACTERIZATION**

RESEARCH GROUP: Camilla Colla, Elena Ferretti, Alessandro Marzani, Giovanni Pascale, Francesco Ubertini, Erasmo Viola

KEYWORDS: NDT, monitoring, effective stress, effective strain, Poisson ratio

The research topics concern the development of innovative and unconventional procedures and testing techniques to be performed in the laboratory and on site for studying building materials, e.g. mortars, bricks, wood, ... with the aim of determining their mechanical and physical properties, such as compression, shear or tensile strength, the elastic modulus, the capillary rise velocity, etc. Moreover, special procedures for testing single materials samples which may have irregular shapes or portions of structural elements taken on-site, also on historic and/or earthquakes damaged structures. A further innovative development in the procedures for the mechanical characterization of materials and assessment of the structure - environment interaction, is represented by the coupling of mechanical tests with non-destructive diagnostic techniques (sonic tests, IR thermography, digital correlation of images, acoustic emission...) or monitoring systems, also wireless (e.g. potential embedded sensors for salt content monitoring in masonry materials).

Among the laboratory procedures, to identify the constitutive law in uniaxial compression, it has been proposed the procedure of the effective law for brittle heterogeneous materials, which produces evidence against the existence of strain-softening and identifies a monotone strictly non decreasing material law for concrete specimens in uniaxial compression, whose average stress versus average strain diagrams, $\sigma$-$\varepsilon$, are softening. The basic idea is that the actual failure mechanism develops internally, with macro-cracks propagating through the specimens from the very beginning of the compression test. In cylindrical specimens, these cracks isolate a resistant inner core of bi-conic shape, which remains intact, while the outer part is expelled along the radial direction and splits into several portions. The actual failure mechanism gradually modifies the resistant structure and, consequently, the resistant area of the specimen.

On-site, minimally invasive testing equipment (e.g. penetrometers for mortars and wood, hammers...) and combined procedures are used to characterize the materials and assess the health-state of the structures.
MAIN PUBLICATIONS


RESEARCH PROJECTS

SMooHS – Smart Monitoring of Historical Structures, Unità di Bologna, European Research project ENV.2007.3.2.1.1.

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MODELING AND DESIGN OF SHAKING TABLE TEST FACILITIES

RESEARCH GROUP: Giada Gasparini, Stefano Silvestri, Tomaso Trombetti

KEYWORDS: shaking table, dynamic tests, modelling, design

Shaking tables represent the main test tool for the evaluation of the dynamic and seismic behaviour of structures. The first tables were realised at the end of the 60’s and at the beginning of the 70’s and were often used for tests of scale models with linear elastic behaviour. Since the first 90’s, they became the object of an extensive research activity for the development of a next generation of such tools capable of offering new and better possibilities. This next generation of shaking tables (Rice University at Houston, University of Firenze, LHPOST shaking table at San Diego, Eucentre in Pavia, ...) is characterised by:

(a) high accuracy in the displacements reproduction,
(b) large dimensions (in order to allow dynamic tests upon small-scale structures, to better capture the post-yielding behaviour),
(c) capability of well reproducing near-fault seismic input (characterised by very large values of peak ground velocity and displacements).

The scientific activity mainly lies in the development of an analytical/numerical model of the dynamic functioning of the shaking table capable of effectively capturing its actual behaviour (creation of a virtual model of the table). This model has revealed to be very useful for: (a) the design project of new shaking tables, (b) for their adjustments, and (c) for the study devoted to the minimisation of the interactions between the table itself and the tests structures.

Recently (2010-2013), the research group planned, designed and directed two experimental shaking-table test campaigns:

1. Tests on a full-scale 3-storey building structure realized with sandwich r.c. panels, at the EUCENTRE Lab in Pavia.
2. Tests on scaled models of flat-bottom silos containing grain-like materials, at the EQUALS Lab in Bristol (UK).

Total publications: 20.
MAIN PUBLICATIONS


RESEARCH PROJECTS


Shake down test for a large shaking table facility (responsabile delle prove di caratterizzazione e messa a punto per una tavola vibrante di ampie dimensioni) 2004: Università di California San Diego (finanz. NISEE – prog. Marco Polo).


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DYNAMIC IDENTIFICATION AND TESTING

RESEARCH GROUP: Pier Paolo Diotallevi, Claudio Mazzotti, Marco Savoia

KEYWORDS: identification, optimization, dynamics test, Wavelet wave, bridge

The research group is involved in the experimental study of the dynamic behavior of civil structures. The problem is particularly relevant because from the dynamic characterization of the system (modes, natural frequencies, damping), the most plausible values of the main parameters governing the numerical models able to simulate the behavior of the structure can be defined by identification techniques.

The study can be split in three main topics: setup of experimental tests, determination of the dynamic characteristics of the structure and processing of data to estimate unknown parameters of models such as stiffness and mass of the system (model updating). Within the first topic, different types of structures such as hospitals, schools, bridges, railway bridges and pedestrian bridges were considered. The tests were carried out either using a forced excitation or environmental excitation (wind, traffic). Both conventional instrumentation and low-cost accelerometers (MEMS) were used. Frequencies, modal deformation and damping were then identified by using methods defined in the frequency domain and in the time domain, such as circle fit, ARMA, ARMAV, Lissajous diagrams and coupled time-frequency methods such as wavelet transforms.

The estimate of the actual values of the parameters of the mechanical properties (material assumptions, constraints, and structural and nonstructural masses), finally, was obtained by solving an optimization process. The research focuses on the study and application of genetic and evolutionary algorithms and their variants, whereas frequencies and mode shapes were assigned. The shape of the error function for different choices of the number of natural frequencies and mode shapes were investigated. In addition, pseudo-experimental or experimental input data were considered. Finally, it was implemented a modified version of an evolutionary algorithm to improve accuracy and speed of convergence.

Fig. 1. Identification of natural frequencies for a building.

Fig. 2. Test of environmental vibration for a flyover.

Fig. 3. Forced vibration test on a pedestrian bridge.
MAIN PUBLICATIONS


RESEARCH PROJECTS

2009-2012: Research Project FADLESS (Fatigue damage control and assessment for railway bridges), sponsored by European Commission within program RFCS (Research Fund for Coal and Steel-FP7); partners of the projects are: PISA ricerche, Riva Acciaio, VCE Holding, K. U. Leuven, LMS International NV, Bauhaus Universitat Weimar, Facultade De Engenharia Da Universidade Do Porto, University of Bologna.

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EXPERIMENTAL TECHNIQUES FOR THE STUDY OF HISTORICAL MASONRY STRUCTURES

RESEARCH GROUP: Andrea Benedetti, Nicola Buratti, Pier Paolo Diotallevi, Giada Gasparini, Cristina Gentilini, Luca Landi, Claudio Mazzotti, Marco Savoia, Stefano Silvestri, Tomaso Trombetti, Francesco Ubertini

KEYWORDS: masonry, consolidation, monuments, seismic vulnerability

The research focuses on the development of consolidation techniques that combine the conservation of monuments with the seismic protection of users. The activity includes:

(1) The development of experimental techniques for non-destructive characterization of the masonry walls. In particular, advanced diagnostic and monitoring techniques are implemented and used in laboratory and on-site, to allow the non-destructive evaluation of the quality, the homogeneity, the degradation and the state of health of structural elements in masonry, wood, and concrete buildings. The development of new procedures for data acquisition, post-processing of the data and data fusion is pursued in order to maximize the potential of these techniques.

(2) The analysis of seismic vulnerability of buildings and masonry bridges. In this context, a simplified methodology for the assessment of the vulnerability of existing RC structures and masonry has been developed (RESISTO).

(3) The definition of consolidation techniques. Various solutions to repair structures have been studied. In particular composite materials with metal or carbon fibers, in a matrix of epoxy or cement-based have been studied. Numerous applications to real cases have been carried out. The results of the analysis were included in the guidelines document developed by CNR for the repair of composite materials CD 200/2004.

(4) Assessment of the structural damage induced by salts on masonry. The shear behaviour of artificially damaged masonry specimens is investigated by means of an ad hoc experimental test. As well known, the shear behaviour of masonry buildings plays a crucial role for structures located in areas prone to seismic hazard.
MAIN PUBLICATIONS


RESEARCH PROJECTS


ReLUIS 2009-2012: Area Tematica 2, Linea di Ricerca 3, Task 1: Sviluppo ed analisi di nuovi materiali per l’adeguamento sismico di volte e cupole in muratura.


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The focus of the research is the development and application of theoretical models and numerical methods for the structural analysis of historic structures.

The actual research activity encompasses a large number of structural issues involving historical buildings, in particular:
- development of coupled multiphase models for the hygrothermal analysis of masonry structures aimed at the evaluation of the stress induced by crystallization of salts;
- development of advanced constitutive models of the mechanical behavior of masonry;
- analysis of the seismic vulnerability of masonry structures, considering both in-plane and out-of-plane mechanisms;
- assessment of the carrying capacity of masonry structures and reserves of security against the stresses might be required as a result of the execution of works of consolidation and restoration;
- development, investigation and evaluation of new methodologies for the integrated, multiphysics modelling of built cultural heritage with the target to support the development of energy efficiency interventions which minimize the primary energy consumption in historic buildings, taking into full account the preservation tasks.

Further research topic concerns the development of multiscale approaches for the structural analysis of masonry buildings in the presence of degradation due to environmental actions, such as capillary suction and crystallization of salts. The multiscale approach allows to accurately capture most of the degradation process – often accompanied by localization of damage in narrow zones, which ultimately leads to failure – still remaining computationally efficient for large-scale structural computations.
MAIN PUBLICATIONS


RESEARCH PROJECTS


Homogenization of elementary cells of masonry by means of the Cell Method, PRIN2006 - Research Unit of Bologna, coordinator: Prof. A. Di Leo.

From survey to structural analysis of Roman constructions in the Vesuvio area, PRIN2005 Unit of Bologna, coordinator: Prof. F. Ubertini.


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The Cultural Heritage evaluation requires a multiphase and integrated diagnostic approach with extended and deepened experimental campaigns, not harmful to the good. The research group works on the advanced development and use of non-destructive and minimally invasive survey techniques and test procedures aimed at determining the health-state of historic structures and their materials (brick and stone masonry, timber). Among these, sonic tests, radar, IR thermography, tomography, penetrometric tests on mortar and timber, micro-coring, lab determinations on historic samples. In addition, structural monitoring, both traditional and wireless, has been carried out. The experience gained has resulted in prestigious projects in the field of Cultural Heritage, such as the 7FP EU Project SMooHS, the agreements with regional architectonic and archaeological Superintendents and with the Galleria dell’Accademia in Florence, for monitoring large marble statues including two Michelangelo Buonarroti works: the famous David and the “Prigione Barbuto”. In big marble statues, the large masses and shapes often cause high stresses in the material, especially in case of earthquakes or other vibrations. This can result in dangerous situations. Thus, non-destructive diagnostic investigations and continuous monitoring by means of minimally invasive, high sensitive and stable systems, able to give early warnings, become necessary. The David presents a severe crack pattern in the lower part of the legs. The cracks’ depths estimation, important for the structural analyses, has been carried out by means of ultrasonic tests, using properly developed and optimized procedures. A wide crack in the “Prigione Barbuto” has been monitored over two years with laser triangulation sensors. The crack pattern of the David is monitored by a fiber optic sensors FBG network, providing remotely recorded and processed information. The system is controlled by a “Smartbrick ®” device, which also measure vibration, inclination and changes in the environmental parameters.

**Fig. 1.** Some structures recently surveyed: Ghirlandina tower and Modena Cathedral (UNESCO sites), Palazzina della Viola, Palazzo D’Accursio, San Barbaziano church (top); Palazzo Malvezzi, load tests on a ceiling, with details of traditional and wireless monitoring systems, and on a timber beam (bottom).

**Fig. 2.** David and Prigione Barbuto at the Galleria dell’Accademia in Florence.

**Fig. 3.** Ultrasound tests at the David and wireless monitoring of salt content in masonry.
MAIN PUBLICATIONS


RESEARCH PROJECTS


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In the last few years, precast construction systems for multi-storey buildings which include in-situ completion are becoming more and more common. They provide a certain degree of hyperstaticity and an adequate resistance to seismic actions to the structure. The research group is interested in the characterization of precast reinforced concrete structural elements such as beams, single- or multi-storey columns, columns anchored to the foundation, beam-column joints and sandwich panels, with regard to the serviceability and ultimate limit states.

The research was carried out conducting lab tests on full-scale specimens and numerical models for the interpretation of the experimental results. The long-term behaviour and the evolution of the strain distribution in the various construction stages of precast reinforced concrete beams constructed by stages have been observed and a fibre model have been proposed to describe the long-term redistribution of stresses in the section. Tests on multi-storey precast columns with only longitudinal reinforcement in the node panel were conducted and a numerical model to predict the critical load was validated. Tests on the behavior of bars anchored in the foundation inside metal box, filled with high-performance mortar have been carried out considering monotonic and cyclic loads (pull-out tests on individual bars with different anchorage lengths and tests on RC columns, anchored in foundation, under cyclic bending and axial force) as well as tests for the evaluation of the cyclic behaviour of full-scale three and four way beam-column nodes.

Currently the research group is also working on innovative wall systems made of concrete and weak reinforcement and on walls made of wooden blocks. Monotonic and cyclic tests have been conducted on full scale specimens in order to characterize the seismic behaviour also, as well as tests for the evaluation of the performance of thermal and acoustic insulation. The group is also working in collaboration with companies for the development of a dissipative beam-column connection for precast reinforced concrete structures designed without seismic criteria.
MAIN PUBLICATIONS

Pollini A. V., Mazzotti C., Savoia M. (2013) Comportamento sperimentale e numerico di un sistema dissipativo per le connessioni di strutture prefabbricate. 15° Convegno ANIDIS, 30/06-04/07/2013, Padova.


RESEARCH PROJECTS

Research Project with APE (Montecchio Emilia - RE) for the study of the mechanical behaviour of precast elements completed on site. Coordinator: Prof. Marco Savoia.

Research Project with REGLASS (Minerbio - Bo) for the development of dissipative beam-column connections in precast reinforced concrete structures.

Research Project with TERZER (Besenello - TN) for the characterization of the mechanical behavior and thermo-acoustic properties of walls made of wooden blocks.

Research Project with ISOBLOC (Soragna - Pr) for the study of innovative block-formwork systems.

2010-2013: Research project funded by the Department of Civil Protection – Reluis, Task 2.1.1: Aspects on the seismic design of new buildings - “Reinforced Concrete Structures” Coordinator: Prof. Spacone

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Fibre reinforced concretes are standard or high strength concretes to which steel, synthetic or natural fibres are added. The properties of this composite materials depend on the characteristics of the different components and on their dosages; in particular for a given percentage volume of fibres the most important parameters are the mechanical and geometrical properties of the fibres, and the fibre-concrete bond. As part of this research, experimental tests have been carried out in order to evaluate the flexural tensile strength of FRC prisms, the long-term behaviour of plain and self-compacting concrete reinforced with either steel or synthetic fibres, the effects of temperature and the durability in aggressive environments of FRC beams. The results of the experimental tests allowed to compare the behaviour, for ultimate and serviceability loads, of elements reinforced with different types of fibres. Using the experimental data gathered, different hinge-based and sectional models were developed to describe the short-term mechanical behaviour of the FRCs as well as constitutive inverse analysis procedures to define the constitutive relationships for the FRCs. The issue of evaluating the long-term behaviour of self-compacting concrete was also addressed as the higher amount of fines suggests the possibility of developing a greater deformation. Several experimental campaigns aiming at the study of both viscosity and shrinkage of SCC have been conducted. The development over time of both longitudinal and transverse deformation as well as other mechanical properties were measured and different stress levels were also considered. Based on the results obtained, a prediction model based on the Model Code 1990 was developed, modified by including the dependence on certain mix parameters and the development of resistance over time. SCC mixes were also used to cast beams in order to observe the development of deflection, the cracking behaviour with time and the residual strength at the end of the long-term loading. Current studies are mainly focused on the mechanical behaviour of SCC made with various types of fibres and recycling aggregates.
MAIN PUBLICATIONS
Buratti N., Mazzotti C., Savoia M. (2010). Long-term behaviour of cracked SFRC beams exposed to aggressive environment. 7th International Conference on Fracture Mechanics of Concrete and Concrete Structures (FRAMCOS), 23-28 May, Jeju, Corea del sud.

RESEARCH PROJECTS
Research agreement with Consorzio Tecnico Produttori Fibre in Acciaio (Technical Consortium of Steel Fibre Producers) “Instantaneous and long-term behaviour of cracked FRC specimens: comparison between steel and macro-synthetic fibres”. Coordinator: Prof. Marco Savoia
2010-2013: Research project funded by the Department of Civil Protection - Reluis tasks 1 and 3: “Reinforced Concrete Structures”; “Development and analysis of new materials for seismic retrofit (including new concretes)”. Coordinators: Prof. G. Manfredi, L. Ascione

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The research group conducts several experimental tests concerning the FRP-concrete bond behaviour and currently is also interested in the FRP-masonry bond behaviour (carrying out tests on bricks and walls). FRP plates and sheets, in various number of layers, of several widths and lengths and with different substrate surface preparation techniques have been considered, together with different test set-ups using traditional instrumentation as well as innovative optical techniques (Digital Image Correlation). The effects of aggressive agents and long-term loads have been considered investigating the FRP-concrete interface creep behaviour. The problem of fire resistance of the strengthening intervention has also been addressed, by testing the effectiveness of different methods of protection. Within the ReLUIS research project, the effect of cyclic loads was studied in order to verify the effectiveness of the strengthening of RC elements subjected to seismic loadings. As for the FRCMs, the group works on the definition of test standards and on the identification of failure mechanisms (for various types of fibers and matrices). The research group was involved in two national and international Round Robin Tests on bond and Prof. Savoia and Benedetti are part of the Committee which drafted the Guidelines CNR DT200/2004 “Istruzioni per la Progettazione, l’Esecuzione ed il Controllo di Interventi di Consolidamento Statico mediante l’utilizzo di Compositi Fibrorinforzati”. The group deals also with pultruded elements, addressing issues related to the development of computational models for the descriptions of the behavior of cellular and thin wall beam sections and has been investigating both experimentally and numerically the long-term behavior of pultruded elements under long-term loadings. Professor Savoia was part of the Committee which drafted the DT205/2007 “Istruzioni per la Progettazione, l’Esecuzione ed il Controllo di Strutture realizzate con Profili Pultrusi di Materiale Composito Fibrorinforzato (FRP)”, of National Research Council (CNR).
MAIN PUBLICATIONS


RESEARCH PROJECTS


RILEM TC 223-MSC Committee “Masonry Strengthening with Composite materials”: member Prof. Mazzotti

Research project with ARDEA and BASF for the study of crisis mechanisms of fiber-reinforced systems.

2010-2013: Research project funded by the Department of Civil Protection - Reluis tasks 1 and 3: “Reinforced Concrete Structures”; “Development and analysis of new materials for seismic retrofit (including new concretes)”. Coordinators: Proff. G. Manfredi, L. Ascione

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ADVANCES MATERIALS AND SMART STRUCTURES

RESEARCH GROUP: Giovanni Castellazzi, Stefano de Miranda, Elena Ferretti, Cristina Gentilini, Lucio Nobile, Giovanni Pascale, Francesco Tornabene, Francesco Ubertini, Erasmo Viola

KEYWORDS: shape memory alloy, functionally graded material, FRP, multistable structure

The research focuses on advanced ad-hoc developed formulations and numerical analysis for modeling the behavior of structural components constituted by innovative materials. Recently, a research line on morphing/bistable structures has been started in collaboration with the Department of Engineering at the University of Cambridge. Morphing structures can undergo large changes of shape without plastic deformations giving the potential for large improvement in cost, weight and reliability.

The research touches numerical simulations for the analysis of shape and stiffness control of slender structures using shape memory alloys components.

The following topics are under study:

(1) functionally graded materials (FGM) plates;

(2) interface behaviour in FRP reinforced structures;

(3) enhanced strength in FRP wrapped concrete columns. The flexural behaviour of concrete beams cracked and strengthened with fiber reinforced polymers has been studied based on fracture mechanics concepts. The dynamic behaviour has been investigated too, for estimating the variations due to cracking and subsequent strengthening on vibration modes, frequencies and damping;

(4) multistable structures (corrugated plates);

(5) finite element approaches for electroelasticity problems;

(6) finite element approaches for laminated composites.
MAIN PUBLICATIONS


RESEARCH PROJECTS

Active and passive reinforcements by means of composites for the technologic innovation of the civil structures., PRIN2002 – Bologna Research Unit. Coordinator: Prof. G. Pascale.

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This research line encompasses the development of numerical simulations for the analysis of cracked structural components. In particular, the research focuses on advanced ad-hoc developed formulations for modelling the behaviour of:

- Cracked piezoelectric media.
- Stress intensity factors.
- Investigation on the behaviour of cracked beams within the stability framework. In particular, beams with one or more non-interacting edge-cracks are considered. The cracks are modelled as massless rotational springs. The spring constant is determined on the basis of the energy released due to the crack and by means of Castigliano’s theorem. This method has been employed to compute exact critical loads for a single cracked column with various end conditions and crack locations. Enforcing displacements, slope, moment continuity and additional conditions related to the presence of the cracks, analytical expressions for the characteristic equations are derived for different crack-to-beam depth ratios, geometry and location of the cracks.
- A new fatigue sensor called smart stress-memory patch, which can estimate the cyclic number, the stress amplitude and the maximum stress from the measurement of crack length and acoustic emission (AE), is proposed to evaluate the fatigue damage of such infrastructure as bridges and ships.
MAIN PUBLICATIONS


RESEARCH PROJECTS

SMooHS – Smart Monitoring of Historical Structures, University of Bologna, European Research project ENV.2007.3.2.1.1.

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The nucleation and growth of cracks can be described by continuum damage mechanics. An internal variable is included in the constitutive law to represent the evolution of microstructural damage. Damage degradation can manifest itself in progressive material softening, for which reason numerical results based upon classical continuum mechanics are characterised by a pathological mesh dependence: to avoid this regularised continuum models have been introduced. Among these are the strain gradient models. We address numerical issues associated with some strain gradient models.

Numerical complication arises from the higher order character of the governing differential equations. A discontinuous Galerkin method has been developed. An alternative approach shows that nonlocal constitutive laws between stresses and strains are not strictly needed to construct a material model. They are required only if we use a differential formulation, in which the length scale is absent since the metric notions have been lost in performing the limit process.

Also the effective law, which is a local constitutive law, is suitable for modelling nonlocal effects if used with a formulation which is nonlocal in itself, such as the Cell Method (CM) is. The research group has focused his attention both on static and dynamic analysis of damaged slender structures.

A new fatigue sensor called Smart Stress-Memory Patch, which can estimate the cyclic number, the stress amplitude and the maximum stress from the measurement of crack length and acoustic emission (AE), is proposed for Structural Health Monitoring (SHM), to evaluate the fatigue damage of such infrastructure as bridges and ships. The fatigue crack growth behaviour of thin electrodeposited (ED) Cu specimen for this sensor is investigated. The modified stress intensity factor is proposed to introduce the master curve of fatigue crack growth, because the fatigue growth behaviour of this patch is affected by the maximum stress and the stress ratio.
MAIN PUBLICATIONS


RESEARCH PROJECTS

SMooHS – Smart Monitoring of Historical Structures, Unità di Bologna, European Research project ENV.2007.3.2.1.1.


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The monitoring of existing cracks can be performed by means of several non-destructive techniques. A part of the research activity has been dedicated to new techniques for SHM (structural health monitoring), with particular regard to the assessment of externally bonded FRP (fiber reinforced polymer) strengthening systems. The use of FOS (fiber optic sensors) has been taken into account, and some new applications have been developed. A ultrasonic technique has been proposed for detecting defects at the concrete-FRP interface.

Defining the crack path numerically is not easy, due to several unknowns: if the direction of crack propagation can be computed by means of one of the existing criteria, it is not known whether this direction will remain constant during crack propagation. A crack initiation leads to an enhanced stress field at crack tip, which propagates into the solid during propagation, locally interacting with the pre-existing stress field. This interaction can lead to modifications of the propagation direction or crack arrest. A numerical code for use with the CM has been developed which returns accurate crack paths for brittle and non-brittle cracks. The CM code has been employed for modelling crack propagation in concrete and masonry.

The main advantage of using the CM for numerical analyses of masonry is that mortar, bricks and interfaces between mortar and bricks can be modelled without any need to use homogenization techniques.

The capability of the CM to handle domains with more than one material has been exploited to capture how the propagation direction changes when the crack overcome the joints or passes from the brick to the interface and to the mortar. The CM code is able to self-compute the position of crack initiation, manage several cracks propagating at the same time, take into account interactions between propagating cracks, self-estimate whether or not one or more cracks bifurcate and follow the propagation of each branch of bifurcation.
MAIN PUBLICATIONS


RESEARCH PROJECTS

SMoHS – Smart Monitoring of Historical Structures, Unità di Bologna, European Research project ENV.2007.3.2.1.1.


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SEISMIC ISOLATION SYSTEMS

RESEARCH GROUP: Pier Paolo Diotallevi, Giada Gasparini, Luca Landi, Stefano Silvestri, Tomaso Trombetti

KEYWORDS: base seismic isolation, HDRB isolator, application to existing buildings

The use of innovative techniques as the insertion of isolators at the base seems to be a promising solution both for the control of seismic effects in new buildings and for the retrofit of existing buildings. For the latter case the objective of satisfying seismic requirements of new structures is often significantly onerous and prohibitive. This occurs especially in case of strategic buildings. The introduction of isolators at the base, as it is known, allows to reduce the accelerations in the structure by an increase of the fundamental period of the isolated structure and a concentration of seismic demand at the level of the isolators. The research works on seismic isolation have regarded in general the different typologies of isolation devices, the modeling of the devices, the design criteria and the applicative problems.

A group of studies have been aimed to evaluate the effectiveness of seismic retrofit through insertion of high damping rubber bearings at the base. Once the isolation system has been designed, the response of the structure has been analyzed considering a 3D model characterized by variable parameters for the isolators and non-linear behaviour for the superstructure. In particular the effects on near-field earthquakes on the response of base-isolated buildings has been investigated and the possibility of using viscous dampers at the base to reduce these effects on isolators has been examined. These studies have been repeated also with reference of new buildings.

The research group has also completed the study of few first applications of PBSD approaches for the seismic retrofits, using base isolators, of existing masonry structures, such as the ex-barracks Zucchi in Reggio Emilia within the bounds of the research project founded by the Italian Ministry of Research titled “Seismic protection of new and existing buildings” (1997), and the Teatro Galli in Rimini within the bounds of the research project founded by the Italian Ministry of Research titled “Seismic retrofit of monumental buildings with seismic isolation and innovative materials” (2000).

Total number of publications: 15.
MAIN PUBLICATIONS


RESEARCH PROJECTS


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OPTIMAL INSERTION OF VISCOUS DAMPERS INTO STRUCTURES FOR THE MITIGATION OF THE SEISMIC EFFECTS

RESEARCH GROUP: Pier Paolo Diotallevi, Giada Gasparini, Luca Landi, Stefano Silvestri, Tomaso Trombetti

KEYWORDS: viscous dampers, shear-type structure, optimal sizing, practical design procedure

Dissipative systems have widely proven to be able to effectively mitigate seismic effects on buildings. However, still the issue is open of how to insert viscous dampers into shear-type structures in order to reach the best dissipative performances of the dynamic system (structure + dampers). The researches carried out at the University of Bologna in the last few years have focused upon the search for the system of added viscous dampers capable of maximising its dissipative effectiveness taking into consideration at once all possible dampers sizing and placement. These researches were performed using both physically-based and numerically-based approaches and have indicated that the mass proportional damping (MPD) component of a Rayleigh damping systems (which is actually physically implementable through a damper arrangement that sees dampers (a) placed so that they connect each storey to a fixed point and (b) sized proportionally to each storey mass) is capable of providing the best overall dissipative properties. This suggests a new and efficient way of inserting viscous dampers in structures to be built in seismic areas, which is alternative to the common (and less efficient) interstorey damper placement. Also, a practical 5-step procedure has been developed for the seismic design of building structures equipped with viscous dampers, which aims at providing practical tools for an easy identification of the mechanical characteristics of the manufactured viscous dampers which allow to achieve target levels of performances.

The group has also developed simplified formulas (in terms of reduction factors for the earthquake forces) for the seismic design of structures which exploit the combined effects of viscous and hysteretic dissipation, as provided by dampers and by post-yielding behavior of the structural members, respectively.

Some other studies regarded finally the use of dampers in the seismic retrofit of existing RC buildings and the proposal of simplified design criteria for nonlinear fluid-viscous dampers.

Fig. 1. Viscous damper in diagonal bracing system.

Fig. 2. Effectiveness of damper systems in shear-type structures.

Fig. 3. Ratio between force reductions factors $d_{\omega} = R_{\omega}/R_{\varepsilon}$ as a function of period and ductility demand.
MAIN PUBLICATIONS


RESEARCH PROJECTS


Progetto RELUIS2, Area Tematica 2, Linea di Ricerca 3, Task 2: “Sviluppo ed analisi di nuove tecnologie per l’adeguamento sismico” (Progetto Esecutivo 2010-2013); Coordinatori: Prof. L. Ascione e Prof. G. Serino; Responsabile della ricerca per l’Unità di Ricerca di Bologna: Prof. T. Trombetti.

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EXPERIMENTAL RESEARCH UPON LARGE LIGHTLY-REINFORCED CONCRETE WALLS

RESEARCH GROUP: Giada Gasparini, Stefano Silvestri, Tomaso Trombetti

KEYWORDS: large lightly-reinforced concrete walls; wood-concrete caisson blocks; pseudo-static tests

Buildings made up of reinforced-concrete walls represent a structural typology which has been widely used in economic public housing. Such building structures characterised by small wall-thickness (15-25 cm) and by small percentage values of steel reinforcement have shown excellent strength resources even against strong earthquake ground motions: the structural overstrength allows to reduce the ductility demand. However, still few experimental and analytical studies have been performed up to now with the aim of evaluating the ultimate (near-collapse) seismic performances of buildings realised using large lightly-reinforced concrete walls.

The research group has recently organised, designed and interpreted (by means of appropriately-developed analytical models capable of capturing the experimental behaviour) a series of experimental tests with cyclic horizontal loading and shaking table tests (conducted at the laboratory of the European Seismic Centre EUENTRE in Pavia) upon a peculiar typology (with non-returnable block-formwork) of lightly reinforced concrete walls. Due to the peculiar conformation of the block-formwork, the structural wall so-obtained is characterised by the presence of lightening alveolar zones. Inside the blocks, before casting the concrete, appropriate horizontal and vertical reinforcement steel bars are placed, so that the structural walls is actually a reinforced-concrete wall. To obtain an adequate characterisation of the seismic behaviour (stiffness, strength, ductility) of such walls, experimental pseudo-static tests with constant vertical loading and increasing horizontal loading have been carried out both upon single walls and upon a H-shaped 2-storey structural system. The results obtained show a good ductile behaviour, yielding horizontal loads comparable with applied vertical loads, and the maintenance of strength to vertical loads after damaging.

Total number of publications: 20
MAIN PUBLICATIONS


RESEARCH PROJECTS
Convenzione C&P Costruzioni – DISTART. Responsabile scientifico: Prof. Claudio Ceccoli.
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DEVELOPMENT AND APPLICATIVE EXAMPLES OF PERFORMANCE BASED SEISMIC DESIGN AND DISPLACEMENT BASED DESIGN APPROACHES

RESEARCH GROUP: Andrea Benedetti, Pier Paolo Diotallevi, Giada Gasparini, Luca Landi, Stefano Silvestri, Tomaso Trombetti

KEYWORDS: Performance Based Seismic Design (PBSD), Displacement Based Design (DBD), case-studies

In recent years innovative methodologies have been proposed for the seismic design of building structures, such as Performance Based Seismic Design (PBSD) and Displacement Based Seismic Design (DBD). The core idea of the PBSD (PEER, Vision 2000, California) resides in the capacity of defining and satisfying a number of given performance objectives (association of a structural performance level to an earthquake design level). The new concept introduced by the DBD (Priestley and Calvi) lies in the development of a design method based upon the displacements (instead upon the forces).

The research group has carried out a comprehensive and complete study of few first applications of PBSD approaches for the seismic retrofits of existing masonry structures (the Palazzo della Civilta Italiana in Roma Eur).

Some of the studies performed by the group have been aimed to the validation of the DBD methodology developed by Priestley and Calvi with reference to new and existing RC structures. Within the related research projects a collaboration is activated for the preparation of a model code and examples. Moreover extensions of the DBD procedure have been proposed for asymmetric structures and infilled RC frames.

The research group is currently developing an innovative approach for the optimal seismic design of structures which encompasses recent scientific contributions in the field. This approach (stiffness-strength-ductility design, SSDD) : (1) defines a set of desired performance objectives for the structure; (2) obtains, assuming a splitting between the lateral- and the vertical-resisting systems and imposing the performance objectives, the characteristics (in terms of stiffness, strength and ductility) of the lateral resisting-system (realised using special bracing elements called “crescent shaped braces”); and (3) checks the satisfaction of the performance objectives by means of non-linear dynamic analyses.

Total number of publications: 42.
MAIN PUBLICATIONS


RESEARCH PROJECTS

Research Project RELUIS Line 4: “Development of displacement based approaches for the design and vulnerability evaluation” (Executive Project 2005-2008); National Coordinators: Prof. Calvi e Prof. Priestley; Chief-responsible for the Bologna Research Unit (Unit n. 2): Prof. A. Benedetti; task: “Reinforced concrete frame structures”.

Progetto RELUIS2, Linea 2: “Development of displacement based approaches for the vulnerability evaluation” (Executive Project 2010-2013); National Coordinators: Prof. G. M. Calvi e Prof. T. J. Sullivan; Chief-responsible for the Bologna Research Unit (Unit n. 2): Prof. A. Benedetti; task: “Reinforced concrete structures with and without masonry infills”.

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MODELS AND PROCEDURES FOR THE NONLINEAR SEISMIC ANALYSIS OF RC STRUCTURES

RESEARCH GROUP: Pier Paolo Diotallevi, Barbara Ferracuti, Luca Landi, Marco Savoia
KEYWORDS: global models, fibre models, nonlinear dynamic analysis, RC structures, nonlinear static analysis

The research group is involved in the development of new analytical models and in the implementation of original computer programs for the nonlinear static and dynamic analysis of reinforced concrete (RC) structures. The prediction and the control of the inelastic response represent, indeed, fundamental elements of the seismic design. The research started with the realization of a new global model based on the subdivision of the elements in segments. A moment-curvature law for cyclic loading has been introduced for the control sections. The model has been extended in order to include the effects of changing axial forces on the moment-curvature relationship. Subsequently it has been proposed a new fibre model based on the flexibility approach, able to account for the nonlinear flexural-shear interaction of RC members. For the concrete fibres a biaxial constitutive relationship based on MCFT theory has been introduced. Both models have been validated through comparisons with available experimental results. The models have been then applied for studying various aspects of the nonlinear seismic response of RC structures.

The pushover analysis, that is a non-linear static analysis performed by applying lateral forces gradually increasing up to collapse, may provide an alternative both to conventional linear methods and to more complex methods based on non-linear dynamic analyses. The pushover techniques require particular attention with regard to some aspects, as the evaluation of seismic demand and the definition of a proper distribution of lateral forces. In particular, several numerical investigations have been performed in order to evaluate the effectiveness of standard procedures, based on single invariant load distributions, and advanced procedures. Among these, the study have examined the multi-modal procedure, aimed to include higher mode effects, and the adaptive procedures, aimed to account for the variation of lateral load vector in the inelastic range. The effectiveness has been evaluated through the comparison with non-linear dynamic analyses with reference to regular and irregular structures in elevation and in plan.

Total number of publications: 42
MAIN PUBLICATIONS


RESEARCH PROJECTS


Eucentre Research Project “Seismic Risk”.

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ANALYSIS OF THE TORSIONAL EFFECTS INDUCED BY THE SEISMIC ACTION IN PLAN ASYMMETRIC STRUCTURES

RESEARCH GROUP: Giada Gasparini, Stefano Silvestri, Tomaso Trombetti
KEYWORDS: plan asymmetric structures, maximum rotational response, seismic excitation

Structures characterized by not coincident centre of mass and centre of stiffness (eccentric structures) when subjected to dynamic excitation, develop a coupled lateral-torsional response that may increase the local peak dynamic response. This behaviour has been investigated by many researchers since the late 1970s. Nevertheless a number of issues still remain unresolved in the areas of inelastic response and development of simplified, yet physically-based design procedures. In particular, in order to effectively apply the Performance-Based Design approach to seismic design, there is a growing need for code oriented methodologies aimed at predicting deformation parameter.

Starting from the governing equations of motion of linear elastic eccentric systems, a key system parameter which controls the maximum rotational response of such systems under free and forced vibration, is identified. This parameter, called ALPHA, is defined as the mass radius of gyration of the structure multiplied by the ratio of the maximum rotational to the maximum longitudinal displacement response developed by a one-story eccentric system in free vibration. A number of numerical, experimental (through shaking table tests of linear elastic and inelastic systems) and field data (from historically recorded structural responses) analyses have shown that the parameter ALPHA is capable of providing a tight upper bound for the maximum rotational response developed by the eccentric systems starting from the knowledge of the maximum longitudinal response of the "equivalent" non-eccentric system.

Total number of publications: 30.
MAIN PUBLICATIONS


RESEARCH PROJECTS

Research project RELUIS Line 2: “Evaluation and reduction of vulnerability of existing RC buildings.” (Executive Project 2005-2008); National Coordinators: Prof. E. Cosenza and Prof. G. Monti; Chief-Responsible for the Bologna Research Unit: Prof. A. Benedetti.

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TRANSPORTATION INFRASTRUCTURES AND TRANSPORTS
INNOVATIVE MATERIALS FOR PAVEMENTS IN TRANSPORTATION INFRASTRUCTURES

RESEARCH GROUP: Giulio Dondi, Andrea Simone, Cesare Sangiorgi, Valeria Vignali, Matteo Pettinari, Claudio Lantieri, Pierpaolo Viola, Francesco Mazzotta, Piergiorgio Tataranni, Luca Noferini

KEYWORDS: pavements, recycling, scrap tires (PFU), construction and demolition waste (C&D)

The growing global awareness on the reduction of impacts on the environment is directing the research towards the use of eco-friendly materials also in the field of transportation infrastructures. Sustainability applied in this field to the design and production of construction materials, finds its basis in the recycling of resources that, otherwise, will be dumped.

Transportation infrastructures offer a number of possibilities to the recycling processes, both for what concerns the recycling of the pavement materials themselves and for the use, in the structural layers, of recycled material coming from other activities, in particular the construction and demolition (C&D) one and the reclamation of scrap tires (PFU) one. Simultaneously, the environmental preservation in the construction of pavements is carried out also through the use of production and construction technologies with low energy consumptions or, in any case, with reduced environmental impact in its broad sense.

In this direction it is spreading the use of cold mixed asphalt concretes (Cold mixes) and AC produced at intermediate temperatures (Warm mixes). The DICAM Roads proposes researches addressed to Management Authorities and Companies that operates in the transportation infrastructures field, providing solutions aimed to the production of recycled and reduced consumption materials with high mechanical performances and low environmental impact.

The study started some years ago and has lead to the definition of admixtures to be successfully adopted in the construction and maintenance of transportation pavements. These innovative materials have equivalent or better performances when compared to traditional materials.

In the adverse economic circumstance for Public Authorities, the proposal of an alternative structural solution with low environmental impact and good performances, to be adopted for new constructions and maintenance interventions, seems to be definitely valid from the environmental and technical point of view.
MAIN PUBLICATIONS


RESEARCH PROJECTS


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FLEXIBLE PAVEMENT SIMULATION WITH DISTINCT PARTICLE ELEMENT METHOD

RESEARCH GROUP: Giulio Dondi, Andrea Simone, Cesare Sangiorgi, Valeria Vignali, Matteo Pettinari, Claudio Lantieri, Francesco Mazzotta

KEYWORDS: Asphalt pavement, Rheology, Asphalt Concrete, Asphalt mastic, DEM

Road pavement performances are still not fully understood because it has been necessary to simplify its materials behavior, modeling them as continuous. In reality, however, they exhibit discontinuous performances, which do not always fit for the advanced continuum models.

Numerous research works, in fact, show that for these types of mixtures it is very important to take into consideration their micromechanical behavior, at the scale of an aggregate particle, because this is an essential factor in terms of overall system performance.

To overcome this limitation, the Distinct Particle Elements Method (DEM), which schematizes a granular material by means of particles that displace independently from one another and interact only at contact points, becomes a good answer. In this way, in fact, is possible to analyze the discrete character of mixes through a microscopic approach.

The aim of the research is the microscale DEM analysis of the interaction between aggregates, bitumen and filler and the evaluation of its influence on the macroscale performances of the asphalt mixture.

The obtained results in previous research works have permitted to evaluate that DEM approach, allowing a very reliable description of real phenomena, represents a valid evolution of the traditional methods in the simulation of the visco-elastic behavior of asphalt mixtures both for small samples during laboratory tests, and for flexible pavements and theirs fatigue performances.

Using the DEM method, moreover, a “virtual laboratory” could be created to study the details of asphalt mixtures that cannot be measured in conventional laboratory tests. With the advancement in computer speed and storage capacity, this approach could be an inexpensive tool to provide a precise control of every variable being studied.

Once the model is calibrated, it could be used to run as many simulations as required. In time, therefore, these models could provide a crucial missing link for the development of true performance-related specifications for asphalt pavements.
MAIN PUBLICATIONS

RESEARCH PROJECTS

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ANALYSIS OF SURFACE CHARACTERISTICS AND MAINTENANCE TECHNIQUES FOR ROAD AND AIRPORT INFRASTRUCTURES

RESEARCH GROUP: Giulio Dondi, Andrea Simone, Cesare Sangiorgi, Valeria Vignali, Claudio Lantieri, Matteo Pettinari, Federico Irali, Riccardo Lamperti

KEYWORDS: Mobile Mapping System, Laser Scanner, Texture, Damage, Maintenance

Knowing the state of the pavement is required in order to establish a maintenance strategy within the Pavement Management System, which optimizes the available resources, ensuring the maintenance of given standards. In this context, the activity of the research group covers two main themes:

(1) the assessment of the pavement conditions: the goal is to develop high performance methods for the characterization of the road geometry and for the evaluation of the state of damage. For this purpose, some research projects are underway both on roads and on runways by using the Mobile Mapping System (MMS) for the measurement of many geometric parameters such as profile, sections, the assessment of longitudinal and cross slopes, the identification of deterioration and for the calculation of status indicators such as PSI and PCI or similar. Other ongoing studies have been started to define new methods for the detection of the skid resistance of surfaces. In particular, the objective is the use of a high precision laser scanning system, a type with triangulation, to analyze the texture of the road surface, obtaining the morphology of the surface of areal basis in addition to the traditional profilometry.

(2) the maintenance of the infrastructure: the purpose is the development of innovative maintenance allowing an easy reinstatement and a quick opening to traffic. Specifically, the ongoing studies focus on: (a) solutions for the functional recovery of the skid resistance through cold laid micro-surfacings containing rubber powder which also have the purpose of reducing noise emissions; (b) solutions for the maintenance works on urban underground networks, including both methods for the prequalification of materials, and techniques for laying and the control of trench reinstatement. These activities are supported by agreements in place at the DICAM and collaborations with the Universities of Belfast, Nottingham and Delft.
MAIN PUBLICATIONS


RESEARCH PROJECTS

Research Project agreement between DICAM and SAVE S.p.A. Upgrading of the infrastructures of the Venice Marco Polo Airport. Year 2013.

Research Project Agreement between DICAM and SITECO Informatica s.r.l. Study of a decision support system for scheduled maintenance of roads. Year 2010.

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ROAD SAFETY DESIGN AND HUMAN FACTOR INTERACTION

RESEARCH GROUP: Giulio Dondi, Andrea Simone, Cesare Sangiorgi, Valeria Vignali, Claudio Lantieri, Riccardo Lamperti

KEYWORDS: Road Safety, Human Factor, Driver psychology, Self-Explaining Roads, Workload management

Road safety depends on the integrated and complex relationship between various components: the driver’s psychology, the traffic, the vehicle, the environment and the road infrastructure. The human element is certainly the most vulnerable, but also the most flexible, in any decision-making process. Road users try to do their best but the task is complex and the environment is not designed to prevent errors occurring this research starts from a different perspective. We believe that in many cases the design of the environment can be further adjusted to human capabilities.

The central theme of this study is to estimate how design principles can reduce the probability of errors while driving. In order to study the driver-road interaction we assess the looking behaviour using a mobile eye tracker.

Specifically, the ongoing studies focus on:

(a) the role of vertical traffic signs in influencing driving and the study of new engineering solutions to make traffic signs more conspicuous;

(b) the transition zones between rural and urban areas and the study of the most common safety measures such as “town gate”, constituted by a restriction of the carriageway with appropriate vertical and horizontal signs;

(c) the understanding of the risks associated with roadside advertising in its various guises so that informed guidelines for the regulation of such advertising can be formulated.

The actual road design standards focus mainly on motorized traffic from a historical point of view, some more “human behavior” and less car-oriented tools for infrastructure safety design are the main aim of this research. Together with the car drivers, the pedestrians, the bike riders, the Powered Two Wheelers users and all the unprotected road users are carried into the focus of concern.

These activities are supported by agreements in place at the DICAM and collaborations with the Psychology Department of the University of Bologna.
MAIN PUBLICATIONS


RESEARCH PROJECTS

Research Project Agreement between DICAM and Provincia di Bologna Road Administration. Road safety analysis of the Province Road N.610 “Selice Montanara”. Year 2013.

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Pavement performance requirements have been progressively evolving, both in terms of quantity and quality, because of changing users’ demands. Particularly, other aspects have become important in the last decades: besides bearing capacity, skid resistance and evenness, the acoustic and vibration pollution caused by road traffic was taken in consideration.

Road infrastructure designers and constructors should mainly be oriented to a search for adequate design criteria and constructive technologies aimed at guaranteeing a reduction in these harmful undesired events.

Vibration phenomena produced by road traffic are very interesting in terms of induced annoyance in the human body and in buildings, especially in urban historical areas. An accurate study of vehicle-pavement-building interaction thus becomes a primary requirement (Fig. 1).

By means of a finite differences technique, the research group developed a numeric analysis in order to evaluate the propagation and reduction of traffic-induced vibration (Fig. 2).

The awareness of the Performance-related Specifications importance has nationally and internationally widespread in the last few years for airport pavement design, but the actual employment of these needs has not. Hence, most of the national Specifications are still Requirement-related without taking into account the pavement serviceability life. This research proposes the use of new procedures and techniques for the surfacings characterization on the basis of the Performance-related procedures already employed in the Italian Specifications. In particular, Gyratory Compactor, ITSM, ITFT, Shear Bond Test and Thermography techniques are suggested for assessing respectively asphalt volumetric mix-design properties, asphalt fatigue fracture and dynamic properties, surfacings bonding properties and binder thermal properties. The obtained results provided also valuable indications for the development of new specifications and Performance-related Airport design procedures (Fig. 3).
MAIN PUBLICATIONS


RESEARCH PROJECTS


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PERSONAL RAPID TRANSIT OPTIMIZATION AND SIMULATION

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KEYWORDS: Personal Rapid Transit, PRT, micro simulation, podcar, ATN, AGT

Car dependency of urban transport is the main challenge for most cities: automobiles produce greenhouse gases; cause a significant number of deaths and injuries; limit accessibility to transport and occupy a disproportional share of urban space, thus preventing the use of more sustainable modes. Yet the car’s convenience remains unquestioned.

A promising emerging public transport technology, called Personal Rapid Transit (PRT), has the potential to attract car drivers where conventional mass transit fails: PRT is a fully automated guided public transportation which became commercially available only recently. With PRT up to 6 persons or light freight travel in small, individually controlled and electrically driven vehicles on a network of light guideways. The narrow guideways is grade-separated; guideways can either be elevated, in underground shafts or on-ground if separated by fences. Due to their small cross section (roughly 1m²) and tight minimum turning radius (ca. 5m), guideways can be routed through streets and buildings at minimum visual impact. From the service point of view, PRT has three distinctive features: (1) passengers can travel from any station of the network to any other station, without intermediate stops or transfers; (2) Passengers do not need to share the vehicle with other passengers; (3) there are no fixed time schedules, vehicles wait at stations or do arrive on demand. This sustainable taxi-alike service is thought to be attractive for many who would currently hesitate to use public transport.

Research objectives are (1) the development of software tools to design and simulate PRT networks; (2) optimal empty and occupied vehicle assignment, (3) network topology optimization (4) stations capacity models (5) development of safe short headway PRT control systems. While offering customized solutions for PRT planning and simulations, we have been cooperating with private consulting firms on the following PRT projects: Masdar, Abu Dhabi, UEA; Heathrow, London Airport; Rimini Congress hall, Italy; Vienna, Suedbahnhof, Austria; Izmit, Turkey.
MAIN PUBLICATIONS


RESEARCH PROJECTS

PRT study at Rimini, supported by the province of Rimini and Europa Inform.

PRT study at Masdar, Abu Dhabi, supported by Systematica S.p.A and Mott McDonalds, UK.

PRT micro-simulator development supported by Novitran, USA and Tabosan, Turkey.

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ENVIRONMENTAL IMPACT ANALYSES OF TRANSPORT SYSTEMS

RESEARCH GROUP: Federico Rupi, Joerg Schweizer

KEYWORDS: impact analyses, sustainable transport, emission models, demand models, traffic counts, micro-simulation

The quantification of environmental impacts and energy consumption of present and future traffic scenarios is becoming increasingly important as guidance for decision makers and for the resource efficient allocation of investments in transport infrastructure and services. The full application of “user pays” and “polluter pays” principle is a goal set out in the European whitepaper 2011 “Roadmap to a Single European Transport Area”. A large variety of data acquisition and processing methods have been developed to estimate the emission of CO2, pollutants, noise, and fuel consumption. Current mobility scenarios have been analysed through traffic counts or surveys. Present and future transport scenario are estimated based on static- and micro-simulation models. Particular attention is devoted to quantify the positive impacts of bicycle mobility and high quality public transport such as Personal Rapid Transit (PRT). Current research is focused on (1) calibrations of generalized cost function model for bicycle ways using geometric information from Openstreetmap and geo-referenced speed profiles from real bicycle trips; (2) calibration of path choice models as support for bikeway planning; (3) development of assessment software based on multi-modal micro-simulation models and the estimation of a virtual population. Once completed this software will allow to estimate the environmental impacts of present and hypothetical traffic scenarios – for instance after the implementation of bicycle ways or public transport services. There have been activities in the following projects: (1) Annual bicycle flow measurements for city of Bologna; radar and tube based 24h bicycle counts and the estimation of increased bicycle usage. (2) Central Europe project BICY: mobility survey, future demand estimation and impact analyses for 13 European cities. (3) Participation in the joint development of the SUMO micro simulation tool, in cooperation with the main developer at the German Aerospace Center, Institute of Transportation Systems Berlin, Germany.
MAIN PUBLICATIONS


RESEARCH PROJECTS

EU 2CE108P2 Project: BICY – Cities & Regions of Bicycles; a project of Central Europe and co-financed by the European Regional Development Fund, ERDF, http://www.bicy.it

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ENVIRONMENTAL, FINANCIAL AND OPERATIONAL PERFORMANCE OF AIRPORTS

RESEARCH GROUP: Luca Mantecchini, Filippo Paganelli, Nicola Gualandi

KEYWORDS: air transportation, airports, level of service, environmental impact, performance evaluation

The air traffic growth and the development of regional airports represent one of the most important by-product of deregulation. The traffic analysis shows that low costs carriers have been largely responsible for passenger growth at a number of regional airports. This scenario has determined a redistribution of air traffic in favor of underused regional airports, characterized by high rates of growth during the last years. Moreover it is widely recognized the importance of regional airports for local communities in terms of increase in air accessibility that determines profound repercussions in the economic development and in the growth of employment. However the prolonged low traffic at regional airports and the insufficiency of land use planning have determined, in many cases, that the suburban sprawl expanded until the airport boundaries. Traffic expansion due to the causes previously described had caused a situation difficult to handle because of externalities generated by air traffic and noise is the principal. The last twenty years have witnessed a tremendous reduction of airplane noise at source. Recent psychoacoustic studies have shown that annoyance is strongly influenced not only by the maximum sound level but also by the number of events. It has been proven that a given level of annoyance can be generated by a low number of noisy aircrafts or by a much higher number of events characterized by a lower level. The adoption of the Directives n. 49/2002/CE and n. 30/2002/CE embodies the purpose of the European Commission of reducing airport noise within the EU. The introduction of airport operating restrictions represents a serious threat for airports expansion. Many international organizations recognize the importance of environmental issues as a threat to the growth of aviation market in Europe, unless airport environmental capacity is efficiently managed. Since noise represents the principal externality of aviation at local level, acoustical capacity seems to be one among the first constraints to airport growth. The need to investigate airport environmental performances with special regard to the parameters closely related with airport management is the focus of this research activity.

Fig. 1. Takeoff radar tracks – Bologna Airport.

Fig. 2. Example of noise contours.
MAIN PUBLICATIONS


RESEARCH PROJECTS

INTERREG IVC Project: D-AIR. Decarbonized Airport Region.

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SAFETY AND REGULARITY OF LAND TRANSPORT

RESEARCH GROUP: Alfonso Micucci
KEYWORD: trasporti ferroviari, trasporti stradali, infortunistica, ricostruzione incidenti

The research conducted by the group is divided into two distinct themes.

The first activity concerns the optimization of decisions and acts to improve the transformation of today local railway services, trough Bologna area, in cadenced and regular Metropolitan Railway Services of SFM project. Especially, starting from an accurate analysis of non-aggregate data about actual railway services frequen-
tation, acquired by Trenitalia and FER opera-
tors, we obtain aggregate values for the future SFM passengers, using forecasting models original designed. Based on these results, combined with service levels provided by SFM project, we study the optimization of rolling stock, doing an analysis of the trains currently produced but also the prototypes currently under development, as well as the characteristics of the rolling stock already available at operators. Finally, we develop an original model implementation of services, based on a limited type of rolling stock, to achieve flexibility of use and economies in handling and maintenance.

The second one concerns the study of the dynamic behavior of a vehicle on the road, the resistances to the motion and the car set-up with the purpose to improve the tires exploitation.

The topic of the road accident study is analyzed: throughout adequate test series, it is empirically determined the vehicle reaction in emergency conditions, in particular the technical time needed for the braking system activation and the maximum deceleration achieved.

For this purpose, representative vehicles belonging to the current available European car stock where equipped with suitable instrumentation and were subjected to stopping tests in emergency conditions, on different types of pavement (asphalt, grass, concrete, gravel and relative combinations) with various weather conditions (winter with wet road surface, summer end with dry road surface).

Fig. 1. Graphic timetable Porretta – Bologna – Imola.

Fig. 2. Braking test.

Fig. 3. Braking diagram.
MAIN PUBBLICATIONS


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WATER ENGINEERING
COASTAL HYDROMORPHODYNAMICS: MONITORING AND MODELLING

RESEARCH GROUP: Renata Archetti, Sara Mizar Formentin, Gabriella Gaeta, Alberto Lamberti, Andrea Natalia Raosa, Achilleas Samaras, Barbara Zanuttigh
KEYWORDS: remote sensing, videomonitoring, hydrodynamic codes, sediment transport, coastal evolution

Near-shore zone morphodynamic evolution – in terms of the bathymetric variability, surface waves, and circulation patterns – is crucial for beach management and inland protection against flooding. Assessment is performed using in-situ monitoring and numerical modelling. Due to the characteristics of both the approaches an integrated use of them is preferred.

DICAM has a consolidated experience in both approaches: development of technologies (instrumentations, software etc.) for the hydrodynamics and morphodynamics monitoring both in laboratory and in the field and development and use of complex, integrated wave-current-sediment numerical models that simulate near-shore processes and wave structures interaction.

Remote monitoring of coastal conditions is a fast growing application of information technology. Video camera systems provide a potentially rich source of information on the state of the coastal zone. DICAM since 2003 has installed several video stations in Italy with the aim to analyse the coastal morphodynamics. On-going studies regards:

- Shoreline detection, beach evolution (Fig. 1), volume changes; bar location, morphology; Times series, trends analyses; Near shore hydrodynamics.
- Moreover DICAM owns several acoustic instruments used to measure velocity waves and water level. Several surveys have been carried out in order to measure: turbulence in the surf and in the swash zone – velocity profiles and waves in presence of coastal defence structures.
- Coastal area hydro-morphodynamic models are applied to describe wave and currents fields and to predict the short, medium and long term of bathymetric changes and coastal evolution associated with such coastal features as groynes, breakwaters and entrance channels.

Research is based on the use of several codes: 2DH MIKE21, Telemac Mascaret, both for wave, hydrodynamics (Fig. 2) and sediment transport simulation (Fig. 3). Coastal evolution model (Litpak) and 2DV hydrodynamic (COBRAS).
MAIN PUBLICATIONS


RESEARCH PROJECTS

EVK3 - CT-2001-0054 COASTVIEW: Developing coastal video monitoring systems in support of coastal management.


National project supported by the Italian Ministry of University and Research. Project: RITMARE. www.ritmare.it/en.


Research contracts funded by ARPA Emilia Romagna on Coastal defence in Igea Marina, Foce Reno, Cesenatico.


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COASTAL RISKS IN A CHANGING CLIMATE
RESEARCH GROUP: Renata Archetti, Stefano Bagli, Sara Mizar Formentin, Alberto Lamberti, Marinella Masina, Andrea Natalia Raosa, Barbara Zanuttigh
KEYWORDS: Coastal flood, climate change, sustainable design, decision support system

Major threats for large stretches of European coasts are erosion and flooding. Climate change may cause very significant impacts on coastal zones, particularly because of the foreseen sea-level rise and increase of frequency and intensity of extreme events (Fig. 1). This research aims at risk assessment and mitigation in short, mid and long term scenarios. Flooding probability and extension are assessed through 1D and 2D numerical modelling. The water level is estimated from tide and combination of set-up and run-up. The 1D investigation is performed on typical beach profiles that are statistically described. Flooding probability and its sensitivity to the most relevant geometric parameters and forcing conditions are examined with the STRUREL code. The 2D map of flood depths and velocities in case of combined storm and river flood is obtained with a standard 2DH Flexible Mesh model, provided that boundary conditions are properly fixed. A 2D simplified model based on the watershed segmentation algorithm has been developed to run multiple flooding scenarios with limited computational effort and sufficient accuracy (Fig. 2).

Coastal defence strategies have to be planned with the aim at sustainable and resilient coasts, considering ecological, social and economic impacts and design optimisation.

Research performed within THESEUS Project has developed a holistic, participatory and interdisciplinary approach to addressing coastal risk based on the Source-Pathway-Receptor-Consequence model. One of the major outcome is the new Decision Support System, a GIS based tool to help decision makers in scoping optimal strategies to minimize coastal risks. The tool allows the users to perform an integrated coastal risk assessment, to analyse the effects of combinations of engineering, social, economic and ecologically based mitigation options, to explore short, medium and long term scenarios taking into account physical and non-physical drivers, such as climate change, subsidence, population and economic growth. The THESEUS DSS is intended as a vehicle for communication, training, forecasting and experimentation.
MAIN PUBLICATIONS


RESEARCH PROJECTS


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The huge potential of the European seas is still far from being recognised and can significantly contribute to the mitigation of climate change effects thanks to the extraction of renewable energy from wind, waves and tides. However these installations are still not competitive in terms of costs, and require design optimization for improving device survivability and conversion efficiency also in milder climates. Due to the massive development of marine infrastructures, it is crucial to adopt a holistic approach towards sustainable use of the marine space.

This research tackles the challenge to combine the installations for renewable energy from the sea, and specifically Wave Energy Converters (WECs), with other off-shore installations for aquaculture, transportation, etc. and with near-shore and on-shore installations for coastal and harbour protection purposes.

The research on floating WECs focuses mainly on the wave loads on the devices, on the design of mooring systems (Fig. 1) and on the hydrodynamics around WEC farms. Experiments have been carried on single and multiple WECs with Power Take Off (PTO) system on board in the wave basin at Aalborg University by varying wave attacks, depth of installation and mooring type (Fig. 2). Numerical modelling of wave-WEC interaction and dynamic response of moorings is performed under simplifying assumptions with the 2DH Mike 21 BW code (Fig. 3) and with the software ANSYS AQWA. Research has been carried out on the development and optimisation of a WEC point absorber specifically designed for the Mediterranean conditions.

The research on WECs integrated in harbour structures has been carried out through laboratory experiments in wave flume on an overtopping devices at Aalborg University and is ongoing with numerical modelling of wave-structure interaction by adopting a 2DV research code based on the RANS-VOF technique.
MAIN PUBLICATIONS


RESEARCH PROJECTS


EU-FP7-Capacities MARINET. Project: REDEM. Reliable design of mooring system of Wave Energy Converters. www.fp7-marinet.eu/.

National project supported by the Italian Ministry of University and Research. Project: RITMARE. www.ritmare.it/en.

Research contract funded by ENEA: Analysis of the existing technologies for the deployment of marine renewable energy along the Italian seas

Research contract funded by INGV: Assessment of the renewable energy potential from the sea offshore the Italian coasts.

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The study of fluids motion in river and torrents is preliminary to the assessment of sediment fluxes and to the final prediction of consequent morphology changes (i.e., the morphodynamics). Engineer applications range from alps to alluvial plains concerning many aspects of human settlement and civil infrastructures. As instance, in mountain torrents, intense and localised storms may cause flash floods with important sediment transport. In steep torrents, the sediment discharge may increase so that the solid concentration often exceeds 40-50%: this is the case of debris flows that transport downstream huge volumes of sediments that are then deposited on the alluvial fans. In addition, a steady discharge in a constant slope channel will not always result in a steady uniform flow. If the channel is sufficiently steep and long, a series of shallow water waves may develop, propagating downstream, eventually break and overtake one another (i.e., roll waves). More downstream river channels tends to divagates in large flood plains changing position of kilometres in decades. In others cases, river-bed degradation of meters was recorded when the channel planimetric position was fixed by flood embankments. All these processes taking place from upstream to downstream parts of the watershed undermine civil structures such as buildings, dams, viaducts, bridges, embankments, pump intakes and the navigation channel. The aim of our research is to develop measurement, experimental and mathematical methods for the optimized design of hydraulic structures and the related assessment of risk inherent in the climate-hydrology forcing term. Field campaigns, laboratory tests were performed and numerical-analytical modelling were implemented also taking advantages from novel underwater-acoustic technologies (Doppler profiler and Multi-beam sonar) and the advancement in computational fluid mechanics (1, 2 and 3 dimensional models).
MAIN PUBLICATIONS


RESEARCH PROJECTS


Yggdrasil exchange program with NTNU-Norway, 2012. Dual-frequency ADCP measurement to quantify suspended sediment concentrations and to determine grain size distribution.


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Non-Newtonian fluids exhibit a complex rheology involving a non-linear relationship between the shear rate and the applied shear stress. Different rheological models have been proposed in literature to represent their behavior: power-law, Prandtl-Eyring, Williamson, and Giesekus models are frequently used. The aim of the research is to study the behavior of these fluids in industrial and environmental applications. The main categories of problems investigated are: (1) Start-up and pulsatile flows of Bingham fluids in different geometries mimicking industrial and mining engineering settings (e.g. flow between two coaxial cylinders). Here approximated analytical solutions were derived with a regularization of the Bingham law and compared with numerical ones. (2) Flow of thixotropic fluids, with a complex molecular structure, whose rheological characteristics change with time, owing to an applied external shear stress. Typical application of thixotropic fluids are electronic packaging, where epoxy and adhesives are used for encapsulation and surface mounting, and the drill industry, in which fluids are subject to cyclic pressure and temperature loads when circulating in the bore. (3) Viscous gravity currents of power-law fluids in plane and radial geometry, representing the intrusion of a non-Newtonian fluid into another driven by a density difference. Closed-form solutions describing the flow field are derived and compared with results of extensive laboratory investigations. (4) Hydraulic jump for muds described by a Herschel-Bulkley constitutive equation fluid in channels of given cross-section. (5) Flow of power-law fluids in porous media in confined and free-surface flow, representing environmental contaminants, remediation agents, and fluids used to enhance oil recovery from underground reservoirs. Approximated closed-form solutions are derived and compared with results of laboratory investigations in reconstructed media. Some of the indicated activities are carried out in collaboration with research groups of the University of Parma (Department of Civil, Environmental, Territory Engineering and Architecture).
MAIN PUBLICATIONS


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The aim of the research consists in developing realistic models for the description of fluid flow, and conservative or reactive solute transport in porous media. The first research line deals with fractured and heterogeneous media as geological heterogeneity strongly affects flow and transport processes. At the same time, the impossibility of a detailed medium characterization through field data, leads necessarily to the adoption of probabilistic modeling incorporating multiscale representations of media. In this framework, complex environmental scenarios, such as groundwater overexploitation and contamination and saltwater intrusion, are investigated by resorting to accurate and efficient computational strategies for the characterization of the uncertainties, in order to make consistent predictions and to provide proper indications for resources management and mitigation actions. The implementation of these strategies represents an important transversal research activity. The approach followed is based on model reduction techniques allowing in a straightforward manner to perform risk analysis, global sensitivity analysis or to solve calibration and optimization problems. To this aim, a numerical code based on the Polynomial Chaos Expansion theory has been developed. This approach is consequently adopted in the other research lines. One of these concerns the investigation of optimum design solutions for the improvement of thermal efficiency of ground heat exchangers. Other studies regard the analysis of parameter uncertainty in non-Newtonian flow in porous domains, seawater intrusion and the adoption of flow and transport formulations in the context of biomedical applications. Some of the indicated activities are carried out in collaboration with research groups of the Politecnico in Milan (Department of Civil and Environmental Engineering), the University of Ferrara (Department of Architecture), the Technical University of Catalonia in Barcelona (Department of Geotechnical Engineering and Geosciences), the Weizmann Institute of Science in Rehovot (Department of Environmental Sciences and Energy Research) and the University of California in San Diego (Department of Mechanical and Aerospace Engineering).
MAIN PUBLICATIONS


RESEARCH PROJECTS


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Climate change, pollution of drinkable water sources, progressive aging of existing infrastructures and limited financial resources render the water cycle management in urban areas one the major issues of the next generations. To effectively cope with the aforementioned problems a new paradigm, aimed to sustainability of water usage, needs to be adopted by decision and policy makers, planners and users. Methods, technologies, field experiences and tools need to be provided to stakeholders to support the planning of infrastructure and water usage adaptation to the anthropic pressures exacerbated by climate change under limited financial resources. This approach requires water companies and research institutions to coproduce methods and tools, and the involvement of decision makers and stakeholders to select objectives and interventions in the urban water cycle aimed to an improved sustainability; the set sustainability targets need to be reached in a strategic horizon of a few decades. The sustainability concept is adapted to include: the assets and the governance domains; the tools needed to test the effects of planned actions on the sustainability objectives and to select the best adaptation path to reach sustainability. These tools include: (1) a metabolism model of the entire water cycle, able to compute mass, energy, pollutant and financial fluxes; (2) a risk model, aimed at quantifying the risk to fail sustainability targets; (3) a DSS to select the sustainability paths. All these tools need to be assisted by guidelines, procedures and inventories of technologies suitably developed. This overall approach at the strategic network level needs to be coupled with: (1) methods for optimizing rehabilitation interventions of water mains via risk analysis (Life Assessment Model); (2) extension of the above methodologies to the management of transport infrastructures and their interaction with the water infrastructure; (3) open source framework for Life Cycle Energy Analysis calculations; (4) evaluation of hydraulic capacity of deteriorating water networks; (5) reliability indicators describing hydraulic and water quality performance at nodal and network level.
MAIN PUBLICATIONS
RESEARCH PROJECTS
EU FP7-ENV.2010.3.1.1-1 ID 265122 Project: TRUST. Transitions to the urban water services of tomorrow. http://www.trust-i.net/
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DESIGN AND MAINTENANCE OF URBAN DRAINAGE SYSTEM DEVICES

RESEARCH GROUP: Sandro Artina, Andrea Bolognesi, Sara Simona Cipolla, Marco Maglionico

KEYWORDS: gully pot, maintenance, management, rehabilitation, storage units

The continuous growth of urban areas and soil sealing impact highlights several problems associated with stormwater disposal. Serious consequences may arise on both hydraulic and environmental sides. Urban catchments are characterised by shorter concentration time than rural areas. As a consequence CSOs activate and spill pollutants into the receiving water bodies when they are still in low flow condition, providing insufficient dilution. A number of studies within urban streams have demonstrated that general stream health declines as the area of impervious cover increases. These effects can be controlled by inserting storage units within the network, whose function is of temporarily accumulating a portion of the rain event volume, and later sending it to the treatment plant or to return it to receiving waters. Larger volumes are required for the hydraulic protection (detention or retention tanks), while smaller first flush tanks provide a mitigation effects on pollutant spills. Ongoing investigations aim to understand the real operation of the reservoirs with respect to the simplified design criteria traditionally used in engineering practice. In addition to tanks, our research is also interested in other relevant components of urban drainage systems, such as roadside gully pots. Their main function is to retain part of the solid material washed off paved surfaces in order to reduce problems associated with sediment transport and deposition in drainage structures. However, these structures are subject to clogging problems that can hardly affect their conveying capacity, leading to street flooding during rain events. Current research has aimed to determine which variables affect the gully pots capability of retaining particulate matter by means of pilot-scale laboratory tests and field monitoring activities. Infiltration and exfiltration in sewer systems deserve further interest: the former may cause groundwater pollution, the latter can generate hydraulic overloads and damage the operation of wastewater treatment plants. Since stakeholders are often not able to bear the costs of all required interventions, it becomes essential to develop tools capable of planning and setting intervention priorities. This research has seen real cases application DSS, based on Bayesian algorithms.

Fig. 1. Gully pot field monitoring.

Fig. 2. Laboratory test facility for exfiltration analysis.
MAIN PUBLICATIONS


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RESEARCH PROJECTS

Research and Consulting Contract with Province of Rimini (2011), Scientific support for the plan for the CSO management in the coastal area of the province of Rimini. Scientific Coordinator: Marco Maglionico.


FP7-ENV-2010 TRUST - Transactions to the Urban Water Services of Tomorrow.

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MONITORING AND MODELLING OF URBAN DRAINAGE NETWORKS

RESEARCH GROUP: Sandro Artina, Andrea Bolognesi, Sara Simona Cipolla, Marco Maglionico

KEYWORDS: numerical model, pollution, sewer networks

Numerical simulation models for urban drainage networks have become increasingly important for both hydraulic aspects (design or verification of conduits and devices) and for environmental issues, with particular reference to the Combined Sewer Overflows impact on receiving water bodies (“first flush” phenomenon).

The models reproduce quali-quantitative processes separating what happens in the drainage network from what happens on the basin’s surface.

Quantitative (hydraulic) aspects, may be outlined as follows: net rainfall calculation, surface runoff and flow through the drainage system conduits. Water quality aspects include: accumulation (build-up) of pollutants on the basin’s surface during the dry weather period, the mobilization and transport (wash-off) of pollutants due to rain, propagation into the drainage system.

In order to estimate the parameters required for a reliable numerical model, long and accurate monitoring campaign are recommended. Actually, monitoring activities are a relevant part in the analysis of quali-quantitative processes, as both qualitative and hydraulic data are useful not just for calibrating the models, but also to understand the studied phenomena.

Numerical simulations, either based on individual rainfall events (real or synthetic) or over long time series allow to evaluate the behaviour of the network and compare the effects of possible interventions in order to mitigate the environmental impact.
MAIN PUBLICATIONS


Artina S., A. Bolognesi, T. Liserra, M. Maglionico, G. Salmoiraghi; Experimental analysis of first foul flush in an industrial area; Transactions on Ecology and the Environment (ISSN 1743-3541), Wessex Institute of Technology Press, 2006.


Calabrò P. S., M. Maglionico; Comparison between detailed and conceptual models in water quality simulation; 9th International Conference on Urban Drainage, 8-13 Settembre 2002, Portland (USA).


RESEARCH PROJECTS


FP7-ENV-2010 TRUST - Transactions to the Urban Water Services of Tomorrow.

Research and Consulting Contract with HERA S.r.l. Ravenna (2011), Scientific support for the numerical modelling of the sewer network of Ravenna. Scientific Coordinator: Marco Maglionico

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The contribution in the enhancement of leakage control methods in water distribution systems is closely related to the need for an integrated water and energy resource management. Both consolidated and emerging technologies and management practices have been analysed in order to improve efficiency in the use of water and energy resources. In fact, leakage can modify the operational conditions of the network and of pumps, causing relevant effects on energy efficiency. The understanding of leakage-energy nexus shows non-trivial relationships and the definition of methodologies and indicator to evaluate the actual level of water demand, leakage and energy consumed is a key issue either under a management or an environmental perspective. Optimization process has been used to determine the configurations representing the optimal scenarios in terms of watergy efficiency, i.e.: the satisfaction of water demand with the lowest possible energy-demanding networks and, among the low energy networks, those showing the highest energy-efficiency. The contribution on the enhancement of leakage control methods in water distribution systems derives from a number of research projects carried out in strictly collaboration with water utilities operating particularly in Emilia Romagna and Marche regions. Recently some real applications of automatic meter readings (Forlì, HERA network; Fano, ASET network; Reggio Emilia, ENIA network) have been considered. Remote monitoring systems are able to read users’ water meters and it is possible to use this feature for a dynamic water balance, and also it is an excellent starting point for a water losses dynamic control approach that links the benefits of active leakage control and the ones of passive leakage control. In conjunction with the previous mentioned aspects, the research activity is regarded the increasing of the energy self-sufficiency of water distribution systems by means the installation of turbine/PAT, assuming that the installations of Micro–Hydro and Mini–Hydro could be seen as a point of convergence between the pressure control (in order to reduce the losses of water) and the exploitation of a renewable energy source.
MAIN PUBLICATIONS


RESEARCH PROJECTS

LIFE08/INF/IT/000308 “WATACLIC - WATER AGAINST CLIMATE CHANGE. Sustainable water management in urban areas”, approvato dalla CE (2010 - 2012).

FP7-ENV-2010 TRUST - Transactions to the Urban Water Services of Tomorrow.


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APPLICATION OF OPTIMIZATION ALGORITHMS TO DESIGN AND OPERATION OF WATER SUPPLY SYSTEMS

RESEARCH GROUP: Sandro Artina, Andrea Bolognesi, Cristiana Bragalli, Matteo Fortini

KEYWORDS: energy efficiency, design, optimization, water scarcity, water supply systems

Water distribution systems are complex and extensive systems, characterized by significant temporal variability of users’ demand and, in some cases, even of supply sources. This means that interventions must be evaluated for different operational conditions. The search for optimal solutions in economic terms, so to satisfy the functional constraints and performance levels, has become more important with the Law 36/94, which introduced the criteria of entrepreneurship, and also the necessity to reduce the environmental impact in terms of water and energy needs for drinking water. Planning and management problems can be translated into an optimization problem where a set of solutions are found, from which the decision maker can find the final one. The optimization problem is of NP-hard type and is extremely complex due to the nonlinearity of the equations of motion and the presence of discrete variables. To overcome these difficulties heuristic algorithms able to explore the solution space in a stochastic way are applied, leaving to the simulator just the numerical solution of the hydraulic equations. Optimization algorithms considered in the research are manyfold. Multi-objective genetic algorithm (MOGA) NSGA-II based on analogy of evolution in nature has been used in collaboration with University of Exeter (UK). Also, in collaboration with CINECA Center, NSGA-II parallelization has been developed. An evolutionary algorithm named GHEST (Genetic Heritage Evolution by Stochastic Transmission) of recent development has been tested on several water distribution networks. Finally, an exact Mixed Integer Non Linear Programming approach has been used in collaboration with the Department DEIS of University of Bologna. The optimization techniques can be applied in the search of appropriate strategies for the mitigation of the effects of water scarcity. Water supply systems have now reached a high degree of complexity. The research may help to improve, through developments of modelling and analysis tools, the assessment of impact on urban area of possible prevention and mitigation actions.
MAIN PUBLICATIONS


RESEARCH PROJECTS

LIFE08/INF/IT/000308 “WATACLIC - WATER AGAINST CLIMATE CHANGE. Sustainable water management in urban areas”, approvato dalla CE (2010 - 2012).

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Modern techniques for topographical survey (see e.g., LiDAR, laser-scanning) enable numerical descriptions of the morphology of riverbanks and floodplain with high planimetric resolution. These techniques triggered research activities related to the application of one-dimensional (1D), quasi two-dimensional (quasi-2D) or fully two-dimensional (2D) hydraulic models. Ongoing research activities make use of these high resolution digital elevation models to reproduce the complexity of the river bed, protected and not-protected floodplains and flood prone areas. Starting from these altimetric information 1D, quasi-2D and 2D hydraulic model are implemented with different geometry discretizations and mesh resolutions. The main objective is to achieve, by means of mathematical simulations, some points of discussions for listed fields of research:
- flood hazard mitigation strategies associated with different floodplain management policies (i.e. open floodplain, dike-protected floodplains or controlled flooding);
- guidelines for the identification of the optimal topographic resolution for hydraulic models (i.e. optimal cross-section spacing and orientation);
- evaluation of flood hazard and vulnerability indicator (i.e. water depth, stage-damage curve) for flood risk mapping, even in cases of levee failure scenarios;
- definition of strategies for an effective management of extreme flood events (e.g. recurrence intervals >> 200 years), such as controlled flooding of areas outside the main embankments.

Research activities are carried out in collaboration with Italian and foreign partners (Po River Basin Authority; Interregional Agency for the Po River; Emilia-Romagna District; District Agency for the Civil Protection; University of Bristol - School of Geographical Sciences; UNESCO-IHE Institute for Water Education, GeoForschungszentrum Potsdam, GFZ, Germany).
MAIN PUBLICATIONS


RESEARCH PROJECTS
Research and Study Agreement: strategic project for flood-risk mitigation along the middle lower reach of the Po River. Po River Basin Authority (Autorità di Bacino del Po).

Scientific activity associated to the donation of the Interregional Agency for the Po River (Agenzia Interregionale per il Fiume Po).

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REAL-TIME FLOOD FORECASTING SYSTEMS

RESEARCH GROUP: Armando Brath, Emanuele Baratti, Attilio Castellarin, Serena Ceola, Alessio Dome-
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KEYWORDS: flood forecasting, real-time updating, precipitation spatial field, confidence bands

Two crucial components of real-time flood forecasting systems are the estimation and forecasting of the meteorological forcing and the use of the last streamflow observations, that allow to update the rainfall-runoff model simulations and to derive an uncertainty assessment of the issued forecast. Such aspects have been analysed in the following research activities:

a) Integrated use of time-series analysis techniques and deterministic rainfall-runoff models for flood forecasting: along with traditional linear stochastic models, non-linear time-series models have been applied, that is Artificial Neural Networks (ANN) and the “nearest neighbours” method, which is a non-parametric regression methodology; such techniques are applied for forecasting the short-term future rainfall to be used as real-time input to the rainfall-runoff model and for updating the discharge predictions provided by the model (see Fig. 1).

b) Estimates and nowcasting of rainfall fields through remote-sensing techniques: the performances of an integrated flood forecasting system, based upon the use of Meteosat satellite derived rainfall maps and of a distributed rainfall-runoff model were first analysed, comparing both the input fields and the obtained streamflow forecasts. A second research topic is the evaluation of system analysis techniques for obtaining short-term (of the order of a few hours) quantitative precipitation forecasting, based on radar images (see Fig. 2).

Another important issue in flood forecasting is the analysis of the reliability and uncertainty of the streamflow forecasts. A technique for assessing the uncertainty of rainfall-runoff simulations was proposed, that makes use of a meta-Gaussian approach in order to estimate the probability distribution of the model error conditioned by the simulated river flow. The proposed technique is applied to real-world case studies, for which the confidence limits of simulated river flows are derived and compared with the actual hydrometric observations (see Fig. 3).

Fig. 1. Real-time updating of streamflow forecasts through simulation error modelling.

Fig. 2. Precipitation fields (time-resolution 15-mins, spatial resolution 1x1 km²) captured by the Doppler radar.

Fig. 3. Observed and real-time simulated streamflow and relative forecast confidence bands.
MAIN PUBLICATIONS


RESEARCH PROJECTS

Research contracts (from 1999 on) with the Regional Civil Protection Agency of Regione Emilia-Romagna.

Italian Research Project of National Relevance 2006, “Advanced techniques for estimating the magnitude and forecasting extreme hydrological events, with uncertainty analysis (SPIE)”, financed by the Italian Ministry of University and Research (MIUR).

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Water resources management and water security are topical issues today in many countries in Europe and other areas. In fact, environmental change, and in particular hydrological change, is inducing relevant perturbations in water resources availability and water demands. This problem is recognized at the international level, as the numerous scientific and governmental initiatives developed in the last decade and dedicated to water security and society clearly testify. It is an extremely complex scientific and technical problem, because the increase of the water demands and the overexploitation of water resources is superimposed to environmental changes that may themselves imply a reduction of water availability. Finding a solution to such a problem requires gaining an improved interpretation of the connections and feedbacks between water dynamics and society. Traditional scientific and technical approaches for water engineering design are based on the assumption that environmental conditions are marginally affected by human influence and therefore the environment is often assumed to be stationary.

The research and consulting activities set up innovative approaches for studying and modeling the mutual interaction between water and humans (socio-hydrology), hence developing new methods for estimating design variables to support engineering design. The ongoing research activities deal with the following subjects:
- identification of optimal techniques for water resources management in a changing environment;
- impact of climate and hydrological change in water resources;
- integrated methods for flood risk mitigation and flood management through an improved mathematical representation of the connections and feedbacks between society and water processes;
- design of hydro-power plants under environmental change;
- environmental impact analysis for human activities;
- large scale analysis of human influence, environmental impact and socio-hydrological feedbacks.
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CATCHMENT CLASSIFICATION AND STREAMFLOW PREDICTIONS IN UNGAUGED BASINS

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KEYWORDS: design-flood, low-flow indices, flow-duration curves, statistical regionalization, rainfall-runoff modelling

The research activities aim at improving our current level of knowledge in the field of streamflow prediction (e.g. the flood occurs on average once every T years, low-flow indices, flow-duration curves, etc.) for catchment lacking streamflow observations (i.e. ungauged basins). This is a fundamental practical issue that needs to be addressed when dealing with several water related problems (e.g. flood-risk management; water-quality and water-availability assessments; feasibility of hydropower plants; design of drinking-water supply, irrigation and reclamation systems, etc.).

The main research activities are:

(A) Classification of river basins to improve the representation of spatio-temporal variability of streamflows. We are focusing on objective classification techniques that combine multivariate analysis techniques (e.g. Principal Component Analysis, Canonical Correlation Analysis) with unsupervised artificial neural networks, such as the Self Organising Maps (see e.g. Fig. 1).

(B) Statistical regionalization. We develop and test regionalization procedures to transfer hydrological information from donor gauged basins to ungauged basins. In particular, we are currently testing the potential of innovative geostatistical procedures (e.g. Fig. 2).

(C) Simulation of streamflows in ungauged catchments through mathematical rainfall-runoff models, whose parameters are identified through innovative techniques that do not require concurrent rainfall and streamflow observations for the site of interest, and are therefore suitable for ungauged basins.

Research activities are carried out in close collaboration with other national and international universities and research institutes (e.g. Polytechnic of Turin, Research Institute for Geo-Hydrological Protection, Italian NRC; GeoForschungsZentrum, GFZ, Potsdam, Germany; Technische Universität Wien, Vienna, Austria; Centre for Ecology & Hydrology, Wallingford, UK; U.S. Geological Survey, Northborough, MA, U.S.; Institute for Environment and Sustainability, JRC).

Fig. 1. Unsupervised classification of ~300 Italian gauged catchments into nine hydrological classes (see Di Prinzio et al., 2011).

Fig. 2. Metauro river: prediction of low-flows (i.e. Q355) along the stream network through geostatistical interpolation (see Castiglioni et al., 2011).
MAIN PUBLICATIONS


RESEARCH PROJECTS

Earth System Science and Environmental Management (ESSEM) Domain: COST Action ES0901 “European procedures for flood frequency estimation (FloodFreq)”.

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RAINFALL-RUNOFF MODELLING

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KEYWORDS: rainfall-runoff modelling; parameterisation; automatic calibration algorithms, data availability scenarios

The assessment of the parameters characterising a rainfall-runoff model is crucial for a reliable simulation of streamflow values. The problem is particularly critical for systemic models, that are based exclusively on the information attainable from the calibration data, but also the choice of a physically-based approach does not generally overcome the need to calibrate at least a part of the model parameters.

The research aims at obtaining indications on the quantity and quality of the calibration data that are needed for a reliable and efficient automatic parameterisation of rainfall-runoff models. Extensive experiments of calibrations and validations of rainfall-runoff models for different scenarios of historical information availability: different meteorological input variables, different methods for estimating the meteorological fields, different spatial and temporal scales of both input and output variables, different length and information content of the calibration record. Such aspects have been considered in relation to a variety of rainfall-runoff models, of deeply different nature: a physically-based distributed model, a conceptual lumped model, systemic, data-driven models based on Artificial Neural Networks.

Furthermore, the Whittle maximum likelihood estimator was proposed for calibrating the parameters of hydrological models. This method may represent a valuable opportunity in the context of ungauged or scarcely gauged catchments. In fact, the only information required for model parameterization is the spectral density function of the actual process simulated by the model. When long series of calibration data are not available, the spectral density can be inferred by using old and sparse records, regionalization methods or information on the correlation properties of the process itself.

Finally, an innovative regional parameterisation approach is proposed, based on the match, in the optimisation process, of a set of streamflow statistics. Such an approach allows the parameterisation of the model also for ungauged basins, based on the regionalisation of the selected statistics as a function of the climatic and geo-morphologic characterisation of the watershed.

Fig. 1. Feedforward neural network for rainfall-runoff forecasting.

Fig. 2. Conceptual scheme of the distributed rainfall-runoff model AFFDEF.

Fig. 3. A modular approach that uses different system-theoretic rainfall-runoff models according to the situation characterising the forecast instant.
MAIN PUBLICATIONS


Toth E., A. Brath, Use of spatially-distributed or lumped precipitation inputs in conceptual and black-box models for runoff forecasting. In: A. Brath A. Montanari E. Toth (Eds). Recent advances in peak river flow modelling, prediction and real-time forecasting - Assessment of the impacts of land-use and climate changes. (pp. 247-261). Ed. Bios (Italy), 2004.


RESEARCH PROJECTS

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