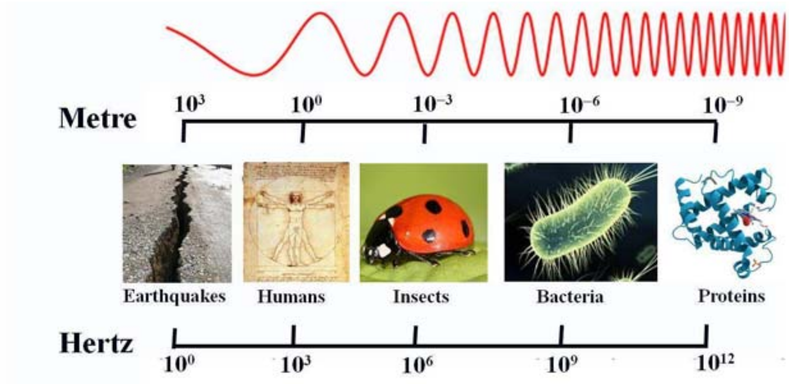
ERC Advanced Grant 2016
Research proposal [Part B1]

Fracto-emissions as seismic precursors

FREM



Cover Page:

- Name of the Principal Investigator (PI): **Alberto Carpinteri**
- Name of the PI's host institution for the project: **Politecnico di Torino**
- Proposal duration in months: **60**

Proposal Summary

The present research proposal is based on the fracto-emissions (Acoustic Emission AE, Electro-Magnetic Emission EME, and Neutron Emission NE) from unstable local phenomena like fracture, turbulence, and buckling, occurring in solids and fluids at the different scales. At the tectonic scale, Acoustic Emission prevails, as well as Electro-Magnetic Emission at the intermediate scales, and Neutron Emission at the nano-scale. TeraHertz pressure waves are in fact produced at the last extremely small scale, and fracture experiments on natural rocks have recently demonstrated that these TeraHertz phonons are able to induce nuclear fission reactions with neutron and/or alpha particle emissions. The same phenomenon appears to have occurred in several different situations, in particular in the chemical evolution of Earth and Solar System through seismicity (rocky planets) and storms (gaseous planets).

On the other hand, at the tectonic scale the different forms of fracto-emission might be used as earthquake precursors. The proposal intends to apply these recently discovered and interdisciplinary phenomena to the solution of an open problem in the field of Civil and Environmental Engineering: the protection against seismic risk.

An innovative experimental approach based on a multi-modal statistical analysis was preliminary tested at a gypsum mine located in Northern Italy. The results obtained during this in-situ monitoring revealed a strong correlation between the three fracto-emissions (AE, EME, and NE) and the major earthquakes occurring in the surrounding area. In particular, it was noted how the acoustic emissions regularly anticipate the earthquakes by about one day, the electromagnetic emissions by three-four days, whereas the neutron emissions by about one week.

Section a: Extended Synopsis of the Scientific Proposal

1. STATE-OF-THE-ART

The present research proposal is based on the fracto-emissions (Acoustic Emission AE, Electro-Magnetic Emission EME, and Neutron Emission NE) from unstable local phenomena (fracture, turbulence, buckling) occurring in solids and fluids at the different scales. It intends to apply recently discovered and interdisciplinary phenomena [1] to the solution of an open problem in the field of Civil and Environmental Engineering: the protection against seismic risk.

SEISMIC PRECURSORS: ACOUSTIC, ELECTRO-MAGNETIC, NEUTRON EMISSIONS

The already established seismic monitoring systems are usually based on the kinematic quantities of the ground motion: displacement, velocity, and acceleration. The last, in particular, is proportional to the inertial forces transmitted by the ground shaking to the structural masses. On the other hand, the use of the fracto-emission precursors will represent a huge step forward, not only for their monitoring capabilities during the earthquake, but also for their forecasting potentialities before the event. This issue, therefore, is the main objective of the present proposal.

A correlation is herein considered between the wavelength scale (which coincides with the crack length scale) and the frequency scale by assuming a constant pressure wave speed [2]. The animals with sensitive hearing in the ultra-sonic field (frequency > 20 kiloHertz) "feel" the earthquake up to one day in advance, when the active cracks are still below the metre scale. Ultrasounds are in fact a well-known seismic precursor [3]. With frequencies between Mega- and GigaHertz, and therefore cracks between the micron and the millimetre scale, pressure waves can generate electromagnetic waves of the same frequency, which turn out to be even a more advanced seismic precursor (up to a few days before) [4].

When phonons show frequencies between Giga- and TeraHertz, and then with cracks below the micron scale, we are witnessing a phenomenon partially unexpected: phonons resonate with the crystal lattices and, through a complex cascade of events (acceleration of electrons, bremsstrahlung gamma radiation, photo-fission, etc.), may produce nuclear fission reactions [5]. It can be shown experimentally how such fission reactions emit neutrons [6], which therefore appear to be as the most advanced earthquake precursor (up to three weeks before) [7]. In addition, it is very important to consider that, in the period before the earthquake occurrence, a very wide area of cracking rocks is active and in a critical condition around the future earthquake focal zone under the influence of tectonic stresses. In particular, Dobrovolsky et al. [8] tried to calculate the dimension of this earthquake preparation area as a function of the magnitude of the incoming earthquake. Assuming that the zone of effective manifestation of the deformations is a circle with the centre in the epicentre of the incoming earthquake, the radius R of this “strain zone” may be up to hundreds kilometres for earthquakes with a magnitude M equal to 5 degrees in the Richter scale and can tend to the whole Earth surface for a M=9 seismic event (for example, Sumatra 2004, Chile 2010, Japan 2011). A comparison between theoretical and field results shows a satisfactory agreement [8]. Moreover, it was also observed that all the precursors tend to fall inside this circle, thus, the monitoring of all those physical phenomena that anticipate the seismic activity can be carried out even at a great distance from the epicentre of the incoming quake.

The piezonuclear fission reactions are often accompanied and revealed by the emission of neutrons and/or alpha particles. However, gamma rays and radioactive wastes appear to be absent in the experiments. Ultra-sonic pressure waves may in turn be produced by the most common instabilities, such as fracture in solids and turbulence in fluids. Both are hierarchical, multi-fractal, and dissipative phenomena, where cracks and vortexes, respectively, are present at the different scales.

After the early experiments conducted at the National Research Council of Italy (CNR) [9], soliciting with ultrasounds aqueous solutions of iron salts, our research group at the Politecnico di Torino has conducted fracture experiments on solid samples, using iron-rich rocks (granite [10], basalt, magnetite [1]), marble, mortar, and steel [1]. Different types of detectors have demonstrated the presence of significant neutron emissions, in some cases by several orders of magnitude higher than the usual environmental background. The neutron flux was found to depend, besides on the iron content, on the size of the specimen through the well-known brittleness size effect [11]: larger sizes imply a higher brittleness, a more relevant strain energy release, and therefore more neutrons.

These studies have also been able to give an answer to some puzzles related to the history of our planet. It has been shown how the piezonuclear reactions that occurred between 3.8 and 2.5 billion

years ago, during the period of formation and most intense activity of tectonic plates, have resulted in the splitting of atoms of certain elements, which were so transformed into other lighter ones. Since the product-elements, i.e., the fragments of the fissions, appear to be stable isotopes, all the excess neutrons are therefore emitted. Several of the most abundant chemical elements have been involved in similar transformations, like a part of magnesium that was transformed into carbon, forming the dense atmospheres of carbon dioxide (CO_2) and methane (CH_4) during the primordial terrestrial eras [12]. In a similar way, calcium depletion contributed to the formation of oceans as a result of fracture phenomena in limestone rocks [13].
These transformations, that have lasted for billion years in the Earth's Crust, have been reproduced in our laboratory in a fraction of a second by crushing different rock samples. We were able to confirm, through advanced micro-chemical analyses, the most relevant compositional variations described above at the geological and planetary scales [10]. Since the natural carbon production in the primordial eras is continuing today due to the seismic activity, a monitoring of carbon dioxide correlated to the major earthquakes will be considered as a potential earthquake precursor, in addition to acoustic, electromagnetic, and neutron emissions.
Even in the case of the other planets of the Solar System we are witnessing a series of experimental evidences [14] that can be interpreted in the light of piezonuclear fission reactions.

2. OBJECTIVES

DEVELOPMENT OF MULTI-PARAMETRIC MONITORING STATIONS FOR SEISMIC RISK EVALUATION

Demonstrating that a strong correlation between the different fracto-emissions (Acoustic, Electro-Magnetic, and Neutron Emissions) and the progressive stages of the imminent earthquake exists, an undoubtable impact onto geophysics and seismology will be produced. Monitoring the different forms of fracto-emission during the failure of natural or artificial materials permits a useful evaluation of the criticality and stability of progressive damage and fracture.
It is well-known the analogy between AE and seismic activity, whose statistical laws of frequency vs magnitude satisfy the same power-law of Gutemberg-Richter. Several AE structural health investigations have been carried out by our research group in the last few years: the Medieval Towers of Alba (Cuneo, Italy), the Asinelli Tower in Bologna (Italy), the Sacro Monte of Varallo (Vercelli, Italy), etc., confirming AE as a reliable earthquake precursor [15].
It is also to consider that the EME signals detected during the failure of structural materials are similar to the anomalous geo-electromagnetic waves detected before major earthquakes, reinforcing the idea that also EME can be applied as a forerunning tool [4].
Recent neutron measurements have led to consider also the Earth's Crust, in addition to cosmic rays, as a relevant source of neutron flux. Neutron emissions measured in seismic areas of the Pamir region (4200 metre a.s.l.) exceeded the usual background level by three orders of magnitude in correspondence to an earthquake of the 4th degree in Richter scale. Additional experimental data on environmental neutrons have been provided by our research group very recently. Such data were acquired at the "Testa Grigia" Laboratory of Plateau Rosa, Cervinia (Italy). Even more recent data refer to experimental trials carried out in Northern Italy, at the seismic district of "Val Trebbia", Piacenza. Evident peaks in the neutron flux show an increment of about six times with respect to the average natural background. This phenomenon has taken place some days before a significant seismic activity (3rd degree in Richter scale).
Based on these earlier analyses, our research group has started from July 2013 a preliminary experimental campaign dedicated to the monitoring of all those physical parameters that tend to anticipate the seismic event. Currently, a first pilot monitoring station has been installed at a gypsum mine located in Murisengo (Alessandria, Northern Italy). The novelty of this experimental investigation consists in the simultaneous acquisition of the three forms of energy emission (AE, EME, and NE) and in their consequent temporal correlation with the incoming seismic event.
As a matter of fact, nowadays several seismic monitoring networks, just based on seismic accelerations, are being utilized all over the World, in California, Mexico, Taiwan, Turkey, Romania, and Japan. However, it does not exist any sort of multi-parametric monitoring method that takes into account the simultaneous observation of different precursory phenomena. Then, applying the methodology and the experimental approach used by our research group in the first pilot-station, it will be possible to realize a suitable monitoring platform to prevent well in advance the effects of seismic events. In this way, the monitoring and the correct interpretation of the

precursory phenomena could provide the basis for the assessment of the three main data of an earthquake: place and time of occurrence, as well as its magnitude.
In particular, the encouraging preliminary results show that a strong and systematic correlation exists between fracto-emissions and seismic activity monitored in the closest area around Murisengo. As an example, in Figures 1a-c it is reported the comparison between a sesimic swarm detected during the preliminary experimental campaign and the correlated fracto-emission distributions. The seismic event refers to the seismic swarm of April 2015 whose main event of 3.2 degrees in the Richter scale occurred on April 11, 2015. From the comparison it can be seen that the fracto-emissions anticipate the seismic activity very clearly, with an evident, although different, shifting.

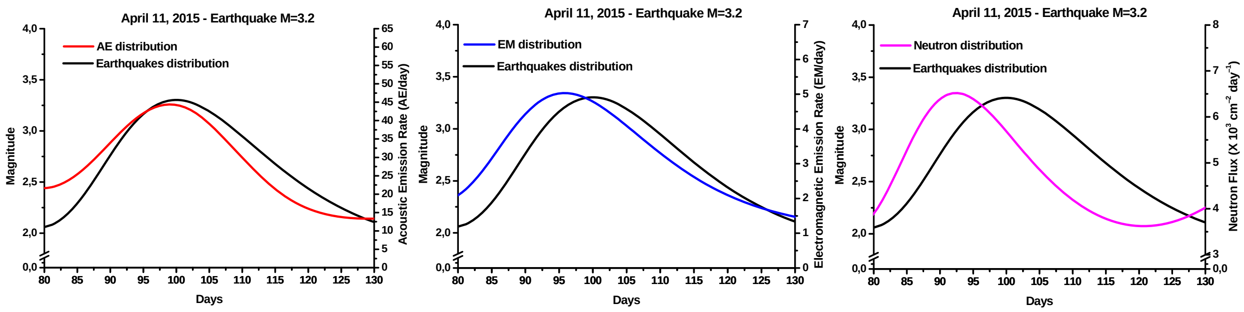


Fig. 1a-c: Anticipated and differently shifted Gaussian distributions of AE/EME/NE events for the earthquake of April, 11 2015

This preliminary experimental investigation can be considered as a basis for the design and installation of additional monitoring stations in other Italian geographical areas where the seismic activity is significantly greater than that in Murisengo.
The first objective of this research proposal is, in fact, the setting up of at least three further monitoring platforms in high seismic risk geographical areas, such as the Italian North-East, the central regions of Italy, and Sicily. As a matter of fact, these areas are often subjected to significant telluric phenomena.
Besides the establishment of these three additional monitoring stations in Italy, it is planned to design and install further platforms in Europe and in other Continents. This is in fact the second objective of the research proposal. A close cooperation with foreign research institutions and universities, involved for many years in seismic prevention, is expected. In particular, our research group intend to collaborate with the University of Athens (Greece), with Caltech (California Institute of Technology, California), and with the Kyoto University (Japan).
Once installed, these innovative monitoring platforms will combine the signals coming from different detectors to assess the monitoring and forecasting capabilities of the proposed method. In addition, it can be assumed to integrate the data coming from the monitoring stations installed in areas with higher seismicity (California and Japan) with the experimental observations of environmental CO2. This is the third objective of the research proposal. Appreciable carbon dioxide emissions were recently observed to occur some days before seismic events [12] and further experimental observation carried out in the Italian Central Apennines [12] indicates that the periods of anomalous carbon dioxide flow rate were related not to human factors, but to the deformative processes of the crust associated to the local seismicity. Thus, the multi-parametric monitoring stations previously described will be developed for the acquisition of the three different fracto-emissions, quantifying also natural carbon increments in relation to major earthquakes in the geographical areas characterized by higher seismicity.
Therefore, during the five years of the project, it is planned to install a total of six monitoring stations (three in Italy, one in Greece, one in California, and one in Japan). Obviously, the pilot station of Murisengo will remain operative and will act as the “reference platform” for the development of additional measurement techniques of the various seismic precursors throughout the duration of the research.

3. METHODOLOGY

A single seismic precursor may not be helpful, so the prediction strategy has to take into account an integral approach that includes the evaluation of several physical quantities and discriminates true signals from the environmental background or noise. In the following, the innovative methodology used by our research group in the pilot station located in the gypsum mine is described. In particular, it is based on an appropriate multi-modal statistical analysis of the earthquakes' temporal distribution and of the related fracto-emissions (AE, EME, and NE).

ENVIRONMENTAL PROTECTION AGAINST SEISMIC RISK

Since July 1st, 2013, a dedicated in-situ monitoring at the San Pietro - Prato Nuovo gypsum mine, located in Murisengo (Alessandria, Northern Italy) has started and it is still in progress.

Currently, a rock pillar of the mine, located at about 100 meters below the ground level, is subjected to a multi-parametric monitoring in order to evaluate the seismic risk of the surrounding area by the detection of the AE/EME/NE fluctuations. Thanks to the position of the monitoring station (100 meters under the ground level), the acoustic and electromagnetic noise of human origin is greatly reduced, as well as the neutron background of extra-planetary origin is between one and two orders of magnitude lower than that on the Earth surface. These aspects make the mine an ideal place for the monitoring of all the phenomena correlated to seismic events, once the low seismicity of the area is considered.

The preliminary experimental results refer to the multi-parametric monitoring carried out during a period of 5 semesters, from July 1st, 2013, to December 31, 2015. The acquisition of acoustic and environmental neutron parameters has started since the first phases of monitoring, whereas only from February 15, 2015, the measuring platform has been integrated with the acquisition of electromagnetic emissions. These experimental observations reveal a strong correlation between the three fracto-emission peaks (acoustic, electromagnetic, and neutron) and the major earthquakes occurred in the closest areas.

In particular, the statistical analysis of the distribution of seismic events and of the three fracto-emissions was performed by means of a multi-modal (multi-peak) statistical approach. Given a specific discrete distribution of points and applying suitable computational routines, the software (Microcal Origin) determines the relative maxima of the distribution and evaluates the best Gaussian fitting by symmetrical or non-symmetrical bell-shaped curves.

Regarding the seismic activity, during the 921 days of the preliminary investigation, 242 earthquakes of magnitude greater than 1.8 degrees in the Richter scale, within a geographical circular area of 100 km radius, were observed. The threshold of 1.8 was selected since, considering the experimental evidences, this was found to be a sort of seismic off-set below which no significant change in the neutron flux was observed.

By applying the multi-modal statistics to the temporal distribution of the 242 earthquakes detected during the five semesters of monitoring, 31 distinct seismic swarms with a maximum magnitude between 2.5 and 4.7 degrees in the Richter scale were identified. Similar multi-modal evaluations were also performed for acoustic, electromagnetic, and neutron emissions.

Besides the multimodal statistical analysis of earthquakes distribution and of the three fracto-emissions, a further temporal correlation between the semester distributions of seismic activity and each related fracto-emission was carried out. The comparison between the temporal distribution of seismic swarms and that of each fracto-emission is given for the first semester of monitoring in the year 2015 (Figures 2a-c).

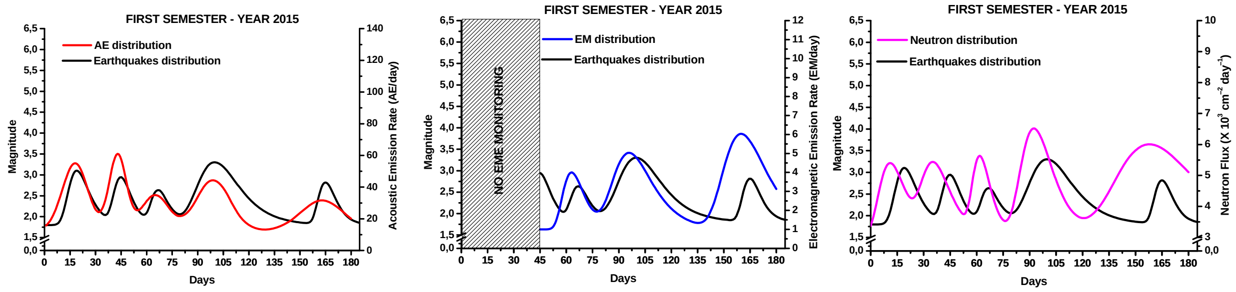


Figure 2a-c: Earthquakes vs (a) acoustic, (b) electromagnetic and (c) neutron emissions temporal distributions for the first semester of monitoring of year 2015.

From the comparison between the different diagrams, it is evident the strong correlation between acoustic, electromagnetic, and neutron signals and the major seismic swarms occurring in the surrounding area, and how the three fracto-emissions tend to anticipate the next seismic event, with an evident, although different, shifting. As a matter of fact, this behaviour was observed in an extremely systematic way for all the 31 identified seismic swarms. In particular, it was noted how the acoustic emissions anticipate the earthquakes by about one day, the electromagnetic emissions by three-four days, whereas the neutron emissions by about one week. Therefore, they should be considered as precursors of the next earthquake rather than aftershocks of the previous one, on the basis of the statistical signal processing and of the different temporal distances. Moreover, the installation of the experimental devices for the acquisition of the fracto-emission parameters in geographical regions characterized by an higher seismicity could be performed at ground level and not necessarily underground as in the case of the Murisengo quarry. More intense fracto-emissions, well distinguishable from the background environmental level, are in fact expected in those cases. In this way, it will be possible to define more accurately the seismic off-set (currently assumed equal to 1.8 degrees in the Richter scale) and to better evaluate the time correlation between each fracto-emission and the incoming earthquake. A longer temporal shifting of each fracto-emission peak with respect to the seismic event is in fact expected.

As regards the choice of the geographic areas for the installation of the three additional monitoring stations, we will refer to the seismic data provided by (INGV - Istituto Nazionale di Geofisica e Vulcanologia) to evaluate the related seismic activities.

As regards the choice of the most suitable areas for the setting up of the multi-parametric platforms abroad, we will refer to the indications provided by the researchers of the different scientific institutions. In this way it will be possible to correlate the data of the new monitoring platforms with those coming from the measuring stations already working in Greece, California, and Japan.

As a further characterization of the future monitoring sites, it is also planned a core drilling in the selected areas in order to obtain rock samples to be tested in the laboratory.

In addition to the standard mechanical tests, usually performed on rock specimens, appropriate investigations by means of Raman spectroscopy will be also taken into account. This technique includes cutting-edge applications in the context of the geological materials. As a matter of fact, Raman spectroscopy is extremely suitable not only for the chemical identification or for the characterization of molecular structures, but also for monitoring the stress effects on rock samples due to seismic activity. Eventually, as regards the evaluation of CO2 in the areas with higher seismicity (California and Japan), the data coming from our monitoring platforms will be integrated with those coming from the Orbiting Carbon Observatory-2 (OCO-2) satellite. This satellite, launched by NASA in July 2014, measures atmospheric carbon dioxide concentrations 24 times per second, revealing where this gas is prevailingly produced.

4. RESOURCES

The feasibility of the proposed objectives is assured by the collaboration of 9 (nine) additional people besides the PI, who will in his turn assure a substantial engagement equal to 50% of his working time, that will be totally spent by the Host Institution.

The Team Members will be the following: One Associate Professor (A1), and one Assistant Professor (A2) from the department of the PI (Department of Structural, Geotechnical and Building Engineering). Two Post-Doctoral Fellows (B1), and (B2) per each year of the research programme. Two Ph.D. Students (C1), and (C2) per each year of the research programme. Highly qualified personnel in the field of low energy physics, radioprotection and theoretical physics will also participate in the project. In particular, it is expected the cooperation of: Dr. Oscar Borla, Research Fellow from the department of the PI; Prof. Massimo Zucchetti, Full Professor at the Department of Energy of the Politecnico di Torino; Prof. Yogendra Srivastava from the University of Perugia.

As regards the equipment to be used to achieve the considered objectives, in addition to the usual testing machines and devices already belonging to our department, the following items will be acquired: (1) Acoustic Emission integrated monitoring system (6 items, total cost Euro 78 000). (2) Electro-Magnetic Emission antenna joined with high-speed oscilloscopes (6 items, total cost Euro 18 000). (3) Neutron energy spectrometre for the energy spectrum monitoring in the pilot station of Murisengo (1 item, total cost Euro 35 000); Neutron detector ATOMTEX at the six platforms (6 items, total cost Euro 42 000), Neutron bubble detectors (60 items, total cost Euro 12 000). (4) Alpha particle detector (6 items, total cost Euro 15 000). (5) Raman spectrometre for the chemical analyses and the evaluation of environment and stress effects on rock samples (1 item, total cost Euro 130 000). All prices are without VAT. Based on the previously evaluated resources, that are necessary to achieve the objectives of our proposal, the total financial support requested is of Euro 2 000 000 subdivided as follows: 920 000 for personnel, 330 000 for equipment, 200 000 for travelling, 100 000 for consumables, 25 000 for publications, 25 000 for audits, 400 000 for overheads.

Section b: Curriculum Vitae

PERSONAL INFORMATION

Carpinteri Alberto

Italian

Born on December 23, 1952

http://staff.polito.it/alberto.carpinteri

EDUCATION

Doctoral Degree in Nuclear Engineering cum Laude, University of Bologna, Bologna-Italy, 1976
Doctoral Degree in Mathematics cum Laude, University of Bologna, Bologna-Italy, 1981

CURRENT POSITIONS

Professor and Chair of Solid and Structural Mechanics, Politecnico di Torino, Torino-Italy, 1986-
Director – "Alberto Castigliano" Fracture Mechanics Laboratory, Politecnico di Torino, Torino-Italy, 1999-
Head, Engineering Division, European Academy of Sciences, Bruxelles, 2016-

PREVIOUS POSITIONS

Visiting Scientist, Lehigh University, Bethlehem-Pennsylvania, USA, 1982-1983
Visiting Professor, University of São Paulo, São Paulo-Brazil, July-August 2010
Assistant Professor of Solid and Structural Mechanics, University of Bologna, Bologna-Italy, 1980-1986
Researcher, Nuclear Power Plants Programme, Consiglio Nazionale delle Ricerche, Bologna-Italy, 1978-1980
Engineer, Technical Office, Breda Fucine, Milano-Italy, 1977

INSTITUTIONAL RESPONSIBILITIES

President of the National Research Institute of Metrology (INRIM), Torino-Italy, 2011-2013
Member and Vice-president of the Board of Directors, National Research Institute of Metrology (INRIM), Torino-Italy, 2006-2011; Acting President, July-November 2009
Head of the Department of Structural Engineering, Politecnico di Torino, Torino-Italy, 1989-1995
Founding Director – Post-graduate School of Structural Engineering, Politecnico di Torino, Torino-Italy, 1990-2014
President, International Congress on Fracture (ICF), 2009-2013
President, European Structural Integrity Society (ESIS), 2002-2006
President, International Association of Fracture Mechanics for Concrete and Concrete Structures (IA-FraMCoS), 2004-2007
President, Italian Group of Fracture (IGF), 1998-2005
Member of the Congress Committee, International Union of Theoretical and Applied Mechanics (IUTAM), 2004-2012
Member of the Executive Board, Society for Experimental Mechanics (SEM), 2012-2014

COMMISSIONS OF TRUST

Nominator of the Global Energy Prize, 2015-
Editor-in-Chief of the International Journal "Meccanica" (Springer, IF=1.949, in three years the issues per year were brought from 6 to 12), 2012-2014
Member of the Editorial Board of thirteen international journals, among which:
"Theoretical and Applied Fracture Mechanics", 1984-2013
"Numerical and Analytical Methods in Geomechanics", 1995-2013
"Strength, Fracture and Complexity", 2003-
"Engineering Fracture Mechanics", 2005-
"Physical Mesomechanics", 2005-
"International Journal of Fracture", 2006-2013
"Strain – An International Journal for Experimental Mechanics", 2009- 2015
Member of the Expert Panel for the Research Evaluation of the Department of Civil Engineering at the Technical University of Denmark, Lyngby-Denmark, 2007
Member of the Evaluation Committee for the attainment of the position of Full Professor at the following Universities: (1) Israel Institute of Technology (Technion), Haifa-Israel, 2011; (2) Indian Institute of Science, Bangalore-India, 2011; (3) University of Athens, Athens-Greece, 2012

FELLOWSHIPS
Fellow of the European Academy of Sciences, Bruxelles-Belgium, 2009-
Fellow of the European Academy of Sciences and Arts, Salzburg-Austria, 2012-
Fellow of the Academia Europea, London-UK, 2013-
Fellow of the International Academy of Engineering, Moscow-Russia, 2010-
Fellow of the Turin Academy of Sciences (founded by G.L. Lagrange in 1783), Torino-Italy, 2005-; Member, 1995-2005
Member of the Istituto Lombardo – Accademia di Scienze e Lettere (founded by A. Volta in 1804), Milano-Italy, 2006-
Member of the Bologna Academy of Sciences, Bologna-Italy, 2011-
Member of the Accademia Teatina per le Scienze, Chieti-Italy, 2006-
Fellow of the American Society of Civil Engineers (ASCE), Reston-Virginia, USA, 1995-; Member, 1985-1995
Honorary Fellow of the International Congress on Fracture (ICF), Ottawa-Canada, 2009-
Fellow of the European Structural Integrity Society (ESIS), Brno-Czech Republic, 2008-
Fellow of the International Association on Fracture Mechanics for Concrete and Concrete Structures (IA-FraMCoS), Jeju-Korea, 2010-
AWARDS
Odone Belluzzi Prize for Structural Mechanics, University of Bologna, Bologna-Italy, 1976
Robert l'Hermite Medal, International Union of Laboratories for Materials and Structures (RILEM), Paris-France, 1982
Wessex Institute of Technology Eminent Scientist Award, WIT, Southampton-UK, 2000
Griffith Medal for Fracture Mechanics, European Structural Integrity Society (ESIS), Brno-Czech Republic, 2008
Jerold L. Swedlow Memorial Lecture Award, American Society for Testing and Materials (ASTM), Philadelphia-USA, 2011
Paul Paris Gold Medal, International Congress on Fracture (ICF), Beijing-China, 2013
Frocht Award, Socuety for Experimental Mechanics (SEM), Indianapolis-USA, 2017
SUPERVISION OF GRADUATE STUDENTS
Supervisor of 30 Ph.D. Students between 1990 and 2015. Presently, most of them are taking University positions in Italy or abroad: four Full Professors, four Associate Professors, seven Assistant Professors, eight Post-doctoral Fellows, three are currently Ph.D. Students, whereas the remaining four are managers in public or private enterprises
TEACHING ACTIVITIES
European Coordinator of the “Innovative Learning and Training On Fracture” (ILTOF) Project, in the framework of the European Union Leonardo da Vinci Programme for Education and Culture (Total financial support = Euro 480 000), 2006-2008
Courses taught at the Politecnico di Torino between 1986 and 2015:
Structural Mechanics (Electrical Engineering, 14 credits), 1986-87
Structural Mechanics (Mechanical Engineering, 14 credits), 1987-2001
Statics (Architecture, 8 credits), 1999-2000
Structural Mechanics (Civil Engineering, 10 credits), 2001-2002
Advanced Structural Mechanics (Civil Engineering, 10 credits), 2002-2010
Theory of Structures (Civil Engineering, 5 credits), 2004-2010
Fracture Mechanics (Civil Engineering, 5 credits), 2004-2010
Static and Dynamic Stability of Slender Structures (Civil Engineering, 6 credits), 2010-
Fracture and Plasticity (Civil Engineering, 8 credits), 2010-
ORGANISATION OF MAJOR SCIENTIFIC EVENTS
Organizer, International ESIS-RILEM-CEB Workshop on “Applications of Fracture Mechanics to Reinforced Concrete”, Torino-Italy, 1990
Organizer and Chairman of the Scientific Committee, IUTAM Symposium on “Size-Scale Effects in the Failure Mechanisms of Materials and Structures”, Torino-Italy, 1994
Organizer and Chairman of the Scientific Committee, 11th International Conference on Fracture (ICF11), Torino-Italy, 2005 (record in the ICF history: 1041 participants)
Organizer and Chairman of the Scientific Committee, 6th International Conference on Fracture Mechanics for Concrete and Concrete Structures (FraMCoS-6), Catania-Italy, 2007
Organizer and Chairman, Mini-Symposium on “Cohesive Zone Models of Fracture and Failure”, 22nd International Congress of Theoretical and Applied Mechanics, Adelaide-Australia, 2008

Section c: Ten Years Track-record

SCIENTIFIC ACTIVITIES AND MAJOR ACHIEVEMENTS

Author of over 800 papers (450 in the last ten years), of which more than 350 (230 in the last ten years) published in Refereed International Journals, on the following topics: fracture mechanics, fatigue crack growth, thermo-elasticity, seismic structures, reinforced concrete, structural monitoring, contact mechanics, fragmentation and comminution, drilling and wear, multi-layered and functionally graded materials, nano-structured and hierarchical materials, acoustic, electromagnetic, and neutron emissions from fracture and earthquakes
h-Index (Scopus) = 42
Total Citations (Scopus) = 6268
Author or Editor of 52 volumes

Three single-authored books published by International Publishers:

A. Carpinteri: Mechanical Damage and Crack Growth in Concrete: Plastic Collapse to Brittle Fracture, Martinus Nijhoff Publishers, Dordrecht (1986), XIII + 234
A. Carpinteri: Structural Mechanics: A Unified Approach, Chapman & Hall, London (1997), XV + 761
A. Carpinteri: Structural Mechanics Fundamentals, CRC Press (Taylor & Francis), Boca Raton (2013), XIV + 498

RESEARH TOPICS AND CUTTING-EDGE RESULTS

Different specific topics have been considered, always giving them a personal and original contribution. In some cases such a contribution resulted to be also innovative, anticipating even by years the trends in cutting-edge research. Among these peculiar aspects, it is significant to recall the following ones:
(1) Application of Dimensional Analysis (Buckingham's Theorem for physical similitude and scale modelling) to the scaling competition between plastic collapse and brittle fracture, which are failure mechanisms governed by generalized forces with different physical dimensions
(2) Interpretation of brittle crack propagation and of stick-slip friction instability in the framework of Catastrophe Theory by René Thom
(3) Application of Fractional Calculus to field and boundary equations of an elastic body deformable only over a fractal sub-set
(4) Solution to the problem of propagation stability of cracks bridged by reinforcements and/or fibres based on rigorous conditions of equilibrium and compatibility
(5) More recent papers deal with fundamental aspects, like the size effects on the friction coefficient and the criticality of rock slopes, the nonlinear and chaotic dynamic behaviour iof cracked or damaged solids, the fatigue limit and threshold with the related scaling laws, the energy emissions from fracture phenomena

TEN REPRESENTATIVE PUBLICATIONS AS SENIOR AUTHOR (LAST TEN YEARS)

[1] Carpinteri, A., Pugno, N., "Are scaling laws on strength of solids related to mechanics or to geometry?", Nature Materials, 4, 421-423 (2005). Times cited without self-citations: 69
[2] Carpinteri, A., Lacidogna, G., Pugno, N., "Structural damage diagnosis and life-time assessment by acoustic emission monitoring", Engineering Fracture Mechanics, 74, 273-289 (2007). Times cited without self-citations: 44
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MAJOR INVITED PRESENTATIONS AT INTERNATIONAL CONFERENCES AND ADVANCED SCHOOLS (LAST TEN YEARS)

Invited Lecture on "Asymptotic analysis in Elasticity: From the pioneering studies by Wieghardt until today", Karl Wiegaardt and George Irwin Centenary Conference on Structural Integrity in the Service of Public Safety, Vienna-Austria, 2007

Introductory Lecture, Mini-Symposium on "Cohesive Zone Models of Fracture and Failure", 22nd International Congress of Theoretical and Applied Mechanics, Adelaide-Australia, 2008

Keynote Lecture on "The mitigation of stress-singularities in linear elasticity", 12th International Conference on Fracture, Ottawa-Canada, 2009

Plenary Lecture on "Energy emissions from fracture of concrete: Acoustic, electromagnetic, piezonuclear", 7th International Conference on Fracture Mechanics of Concrete and Concrete Structures", Jeju-Korea, 2010

Opening Lecture on "Evidence of piezonuclear fission reactions: Neutron emissions, microchemical analysis, geological transformations", 9th Youth Symposium on Experimental Solid Mechanics, Trieste-Italy, 2010

Honorary Lecture on "Dimensional analysis and fractal modelling of fatigue crack growth", ASTM Fracture and Fatigue Conference, Anaheim-California, USA, 2011

Closing Lecture on "Piezonuclear reactions produced by brittle fracture: From laboratory to planetary scale", 19th European Conference on Fracture, Kazan-Russia, 2012

Honorary Presidential Lecture on "Piezonuclear fission reactions due to fracture and earthquakes: From the chemical evolution of our planet to the so-called cold fusion", 13th International Conference on Fracture, Beijing-China, 2013

Invited Lecture on "Piezonuclear fission reactions from fracture and turbulence: The chemical evolution in the planets of the Solar System", European Academy of Sciences, Toulouse-France, 2013

Distinguished Lecture in Solid Mechanics on "Acoustic, electromagnetic, and neutron emissions from brittle fracture and earthquakes", California Institute of Technology, Pasadena-California, USA, 2014

Invited Lecture on "Hydrogen embrittlement, microcracking, and piezonuclear fission reactions at the Ni and Pd electrodes of electrolysis "cold fusion" experiments", 12th International Conference on Nanostructured Materials, Moscow-Russia, 2014

Invited Seminar on "Acoustic, electromagnetic, and neutron emissions from brittle fracture and earthquakes", Perm State University, Perm-Russia, 2014

Keynote Lecture on "Opto-acoustic and neutron emissions from fracture and earthquakes", Annual Conference and Exposition on Experimental and Applied Mechanics, Costa Mesa-California, USA, 2015

Opening Lecture on "Static-kinematic duality in beams, plates, shells and its central role in the Finite Element Method", International Conference on Shells, Plates, Beams, Bologna-Italy, 2015

MAJOR RESEARCH GRANTS (LAST TEN YEARS)

In the last ten years, the following research grants exceeding Euro 500 000 were coordinated as:

(1) Project Leader, Italian Ministry of Education, Research and University, "Process Development, Innovative Methods of Implementing and Design of Composite High-tech and Coating Ceramic Materials" (PROMOMAT), 2002-2005

(2) Project Leader, Italian Ministry of Education, Research and University, "Fracture Mechanics Advanced Applications to Ductility and Durability of Reinforced or Retro-fitted Structural Elements" (PRIN), 2010-2012

(3) Project Leader, Regione Piemonte, "Preservation, Safeguard and Valorization of Masonry Decorations in the Architectural Historical Heritage of Piedmont" (RE-FRESCOS), 2010-2013

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2. Solid state physics

Ashcroft N. W., Mermin, D. N.: Solid State Physics, Cengage Learning, Delhi, 2013.

3. Acoustic emission from fracture

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4. Electromagnetic emission from fracture and earthquakes

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5. Theoretical models in nuclear physics

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15. Acoustic emission from earthquakes

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