INSPIRE

Final Dissemination Conference

Athens, 25 & 26 May 2023

Organized by the
National Technical University of Athens

Project partners

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Foreword

This 2-day long dissemination event is open to students and researchers, engineers and practitioners in the field of infrastructure, noise and vibration control and protection from natural hazards, as well as to the general public. It aims to wrap-up and present the main findings of a major research project focused on the use of innovative materials (metamaterials) as solutions for seismic isolation and vibration control.

Metamaterials are structures, or systems of structures, engineered to control or manipulate seismic waves. Their design is based on the ability of arrays of periodically repeated unit blocks to interact, control, and as much as inhibit the propagation of seismic waves.

In the framework of the EU-funded ITN_INSPIRE project, the outstanding properties of metamaterials were explored within several PhD theses, investigating a variety of possible applications, such as:

- Layouts of pile groups and foundation unit blocks installed in the soil to “trap” or redirect seismic waves and limit free-field motion.
- Resonant (meta)barriers, consisting of cells with an internal vibrating mass, are embedded in the perimeter of a structure to isolate it from seismic actions.
- Elastic cloaks (metasurfaces) for mitigation of surface waves (Love and Rayleigh waves).
- Vibration control devices employing negative stiffness elements and directional inertial amplifiers for seismic retrofitting of structures.
- Passive mechanical systems encompassing multistable behaviour, with possible applications in the field of force-limiters and soft mechanisms.

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Thursday

Morning Sessions

Novel Negative Stiffness Vibration Absorbers for Horizontal and Vertical Seismic Protection of Structures

by Evangelos Sapountzakis

The scope of this presentation concerns the mitigation of ambient vibrations, such as earthquakes, on civil engineering structures. Specifically, two individual aspects are examined. The first deals with horizontal seismic protection of multi-story building structures, while the second with vertical seismic protection. The proposed vibration absorbers are based on the KDamper oscillator. The KDamper is a novel passive vibration isolation and damping concept, based essentially on the optimal combination of appropriate stiffness elements, including a negative stiffness element. The design of the KDamper-based absorbers follows an engineering-criteria driven optimization procedure, with proper constraints and limitations depending on the structure to be employed. The excitation input is selected according to the provisions of the seismic design codes, with respect to the considered application. Finally, two alternative displacement-dependent configurations are proposed for the realization of the negative stiffness element, generating one and two-dimensional negative stiffness, respectively. The performance of KDamper is assessed with representative case studies, and its effectiveness is verified by comparisons with existing vibration absorption approaches found in the literature. On the basis of the obtained results, the KDamper-based vibration absorbers can provide a realistic alternative to the existing horizontal and vertical seismic isolation approaches, as well as provide viable retrofitting options for seismic protection.

Dr. Evangelos Sapountzakis is Civil Engineer, Professor at the Institute of Structural Analysis and Antiseismic Research of the Structural Engineering Department of the School of Civil Engineering of the National Technical University of Athens (NTUA). He is also Vice Rector for Finance, Programming and Development of NTUA, Director of the Interdisciplinary Postgraduate Program “Structural Design and Analysis of Structures” of NTUA and Director of the Institute of Structural Analysis & Antiseismic Research. He obtained his Diploma from NTUA in 1984, the MSc and DIC degrees (Concrete Structures) from Imperial College of Science and Technology of London in 1985 and the PhD degree from NTUA in 1991.

He has extensive experience (over 35 years) in the design and analysis of bridge and other largescale structural projects, while since 1996 he has provided consultancy services in various structural and transportation large scale Civil Engineering projects. He has also been a member of the Special Scientific Tender Evaluation Committee for the project: “Study - Construction, Self-financing and Utilisation of the Permanent Bridging Project of Rion - Antirrion”. Apart from NTUA, he is also Professor of Structural Analysis at the School of Corps of Engineers of the Hellenic Army since 1986 and member of the Coactive Educational Staff of the Hellenic Open University (2011-2017). His published research work comprises 132 original papers published in international journals and 190 papers published in international conference proceedings. He is the author of 12 Chapters in books published by International Publishing Companies, 5 Technical Reports, 4 educational books and co-author of 3 educational books. He is the editor of 6 Books or Conference Proceedings. He has participated in 15 financially supported research projects, while in 11 of them as the Principal Investigator. He has given 1 Plenary and 21 Keynote lectures in international conferences. His research work has received intentional recognition, since he is Honorary Editor, Editor-in-Chief, Academic Editor, Regional Editor, Associate Editor of international journals, member of the editorial board of 29 international journals, member of 72 scientific advisory committees of international conferences, while more than 3000 citations have been noticed in international literature (h-index=28). He is also reviewer of scientific papers in more than 60 international journals and evaluator of research proposals of Ministries of Science, Research and Development of 3 foreign countries.

Thursday 25/05, 9:30 – 10:00

Optimization and performance of metastructures for seismic isolation of industrial equipment

by Oreste S. Bursi

This lecture aims to present the seismic mitigation of a typical storage tanks and small nuclear small modular reactor (SMR) where extreme loading conditions are considered by the safe shutdown earthquake (SSE). Thus, to protect the equipment from strong earthquakes, finite locally resonant multiple degrees of freedom (MDoF) metafoundations were developed; and resonator parameters were optimized by means of an improved frequency domain multivariate and multi-objective optimization procedure. Also, the stochastic nature of the seismic input was taken into account. It is proposed: i) a linear metafoundation endowed with multiple cells, linear springs and linear viscous dampers; and ii) a foundation equipped with additional nonlinear vertical quasi-zero stiffness (QZS) cells. With this arrangement, additional flexibility and dissipation against non-symmetrical modes of the SMR and vertical seismic loadings are proposed. It was shown in both cases, how each metafoundation was successfully optimized via a sensitivity-based parameter grouping strategy and a hybrid grid searching algorithm. Thus, the performance of the optimized metafoundations was assessed by means of frequency and time history analyses; and finally, results were compared with industrial equipment endowed with both rigid foundation and conventional base-isolation solutions.

Oreste S. Bursi graduated in Mechanical Engineering at the University of Padua in 1984, and achieved his PhD. in Mechanical Engineering at the University of Bristol. He worked as a visiting professor at the University of Boulder, Colorado, in the period 1989-1990 and at the University of Bristol in the year 2005. He is a full professor of Structural Dynamics and Control at the University of Trento, teaching Seismic Engineering, Theory and Design of Bridges and Mechanics and Structural Design for Energy Engineering. The actual research activity is mainly devoted to the vibration mitigation of industrial equipment due to natural hazards via metastructures, non-linear dynamics, structural identification and steel structures. He has been the coordinator of several EU and national research projects.

For further information, please refer to the URLs:
https://oreste.bursi.dicam.unitn.it/
https://r.unitn.it/en/dicam/nhmsdc

Thursday 25/5, 10:00 – 10:30

Configurational mechanics of variable-length systems

by Francesco Dal Corso

Nonlinear structural mechanics breaks the limits of traditional linear elastic design, to create elements working much beyond the realm of linearized kinematics, fully inside the nonlinear range, so matching the strong requirements imposed by soft robotics, flexible locomotion devices, metastructures, architected structures for vibration mitigation, and morphable structures. Within this context and with reference to variable-length one-dimensional flexible systems, the following recent results are presented:

- The action of configurational forces on elastic structures is theoretically and experimentally proven in the presence of a specific movable constraint: a frictionless, perfectly smooth and bilateral sliding sleeve. In particular, the presence of an outward configurational force at the exit of the sliding sleeve is disclosed both via variational calculus and independently through an asymptotic approach.
- An elastic rod constrained by a frictionless sliding sleeve ending with a linear spring and subject to a dead load at the other end displays (i.) an increase of buckling load at decreasing of elastic stiffness; (ii.) a finite number of buckling loads; (iii.) more than one bifurcation loads associated to each bifurcation mode; (iv.) a restabilization of the straight configuration after the second bifurcation load associated to the first instability mode. Moreover, in the case that the constraint is tilted with respect to the dead load direction, an 'asymptotic self-restabilization' in the following sense: although bifurcation does not occur because the system is imperfect, the deflection initially grows and subsequently decays up to vanish during a monotonically increasing loading.
- A rod subject to transverse forces (twist or bending) and frictionless constraints generates a longitudinal propulsive force realizing (torsional or flexural) locomotion. This motion occurs by transforming elastic energy in kinetic energy.
- The sudden release of a rod partially inserted into a frictionless sliding sleeve is shown to be strongly affected by the action of configurational forces. During its motion, the elastic rod dances by alternatively slipping in and out from the sliding sleeve. The nonlinear dynamics eventually ends with the rod completely injected into or completely ejected from the constraint.

The presented structural systems are modelled as nonlinear elastic structures and solved analytically. Physical models have been designed, realized and tested, confirming the theoretical predictions. These results represent innovative concepts ready to be used for enhancing the efficiency of retractable/extensible soft actuators towards advanced technological applications.

Francesco Dal Corso is currently an Associate Professor of Solid and Structural Mechanics at Department of Civil, Environmental and Mechanical Engineering of the University of Trento, Italy. After earning a PhD in Materials and Structural Engineering at the University of Trento, Italy, he had a postdoctoral fellowship at the Department of Applied Mathematics and Theoretical Physics, University of Cambridge, UK.

His research activity is devoted to the Mechanical behaviour of Solid and Structures. In particular, he dealt with problems related to the localization of deformation, plasticity, large deformations, homogenization, higher-order continua, stress concentrations and singularities, contact mechanics, configurational mechanics and stability. He has co-authored more than 40 journal papers. He has co-guest edited a Special Issue of the Journal of the Mechanics and Physics of Solids in 2020 and he is Associate Editor of Frontiers in Mechanical Engineering - Solid and Structural Mechanics section, since 2021.

Thursday 25/05, 11:00 – 11:30

Seismic design of NPPs: some elements of comparison between nuclear buildings with base raft vs. nuclear buildings with seismic isolation system

by Silvano Erlicher

Nuclear power plants (NPPs) are usually designed accounting for several accidental actions, like, among others, earthquake. Despite high design peak ground accelerations (PGA), NPP buildings are seldom designed with a seismic isolation system. The lecture presents some examples of NPP buildings, with some details about standard seismic design methodology. Then, two case studies of NPP with seismic protection system based on seismic bearings are discussed with their advantages and drawbacks. Metafoundation approach is briefly mentioned at the end, in order to open the discussion about real advantages of this solution for NPP.

Silvano Erlicher graduated in Civil Engineering at the University of Trento in 1999, where he also achieved his PhD in Seismic Engineering in 2003. He was Post-doctoral researcher at LCPC-IFSTTAR in 2003 (Paris, France) and was assistant professor at Ecoles des Ponts et Chaussées (ENPC, Paris, France) from 2004 to 2009. He obtained in 2009 the “Habilitation à Diriger des Recherches (HDR) – Qualification to supervise research”. He joined Egis Nuclear, a French company with 50 M€ annual turnover, in 2009, as principal engineer and became the CTO (chief technical officer) in 2014. He was member of the Scientific and Technical Committee of the French association of Earthquake Engineering from 2014 to 2021. He is author of more than 40 papers in top journals of Structural Dynamics, Earthquake Engineering, Computational Mechanics, Mechanics of Materials.

Thursday 25/05, 11:30 – 12:00

Thursday

Afternoon Sessions

Exploitation of nonlinearity for structural vibration attenuation

by Kyriakos Chondrogiannis

The control of mechanical vibrations is a major topic of interest in the engineering field. The challenge becomes particularly important regarding structural applications. Seismic waves typically consist of unique characteristics, such as low frequency content and large wavelengths, when propagating in soil. Traditional solutions of passive vibration mitigation devices include the attachment of secondary oscillators, such as tuned mass dampers, which require the addition of large mass. In an attempt to improve passive isolation methods, the use nonlinearity can be explored. Geometrically nonlinear elements have the property of variable stiffness depending on the displacement amplitude. Suitable exploitation of this effect can lead to the creation of negative stiffness, a phenomenon that is highly investigated for vibration mitigation applications. Periodic arrangement of geometrically nonlinear unit cells can form metamaterial lattices, with the aim of preventing wave propagation at low frequencies, within the so-called bandgap. These can be placed in the form of metabarriers, surrounding a soil area within which a structure is placed, obstructing wave propagation and thus protecting the structure. The nonlinear cells can additionally be placed on the structure, altering is dynamics, targeting at the attenuation of vibrations. Analytical solutions, numerical analyses and experimental testing on realistic building structures verify the capabilities of such devices to mitigate the dynamic response of a protected structure under seismic input. The application of the investigated configurations does not require the addition of large masses, offering an advantage over linear solutions. The effect of the nonlinear devices towards structural protection is demonstrated, offering potential for practical applications.

Kyriakos obtained his diploma in Civil Engineering from the National Technical University of Athens (2019), in the discipline of Structural Engineering. He defended his thesis in the field of steel structures, studying the behavior of shell formed wind turbine towers with the use of nonlinear analyses. During his first academic years, Kyriakos participated successfully in technological competitions of scaled model vehicles. Regarding his professional experience, he has worked in steel structure design and CFD analysis. Kyriakos joined the Chair of Structural Mechanics and Monitoring at ETH Zürich in 2019 as a PhD candidate. His research lies within the "INSPIRE" ITN Marie Skłodowska-Curie research program, working on metamaterial developments for structural protection.

Thursday 25/05, 13:30 – 14:00

Application of the Extended KDamper (EKD) to the seismic protection of bridges: design optimization, nonlinear response & SSI

by Maria Antoniou

The seismic performance of a representative highway bridge equipped with a novel passive vibration absorption device (the EKD system) is investigated. An optimization process is developed and applied to the EKD design, highlighting the need to incorporate earthquake motion characteristics in the design process to ensure the effectiveness of the isolation system for a wide range of input seismic motions. With the aid of nonlinear 3D dynamic time history analyses (where the hysteretic response of the positive stiffness elements and the nonlinear nature of the negative stiffness elements are explicitly simulated), it is shown that EKD nonlinearities may lead to residual deck drifts. The nonlinear EKDs display a variation in maximum drifts and accelerations of the order of ± 20% compared to the preliminary (linear elastic) design for the examined set of spectrum-compatible motions. Soil–structure interaction (SSI) effects are explored and shown to play a significant role in the seismic response of the system. A direct comparison of the bridge on EKDs and conventional seismic isolation (elastomeric bearings) confirms the superior performance of the EKDs in terms of maximum deck drifts and base shear, while the two systems are found to be equivalent in terms of maximum deck accelerations.

Maria Antoniou graduated from the School of Civil Engineering of the National Technical University of Athens (Greece) in 2013, where she defended her thesis in the field of Soil-Structure Interaction and Earthquake Engineering. She received her Master's degree with distinction from the University of Dundee (UK) in the field of Geotechnical Engineering, with a specialization in Offshore Geotechnics. She is currently a PhD candidate at ETH Zurich (Switzerland) and her main research interests include: (1) numerical modelling of the response of novel seismic isolation systems, (2) numerical and experimental investigations of the life-cycle performance of foundations in the offshore environment, and (3) seismic risk assessment and resilience-based design of various types of infrastructure. She has participated as a consultant in several technical projects with an emphasis in soil dynamics and earthquake engineering. She is a published author in peer-reviewed journals and conference proceedings. She was actively involved in the organization of the 1st, 2nd, and 3rd International Conferences on Natural Hazards and Infrastructure (ICONHIC).

Thursday 25/05, 14:00 – 14:30

Cloaking strategy for Rayleigh waves

by Zinon Chatzopoulos

In this work we design a cloak for Rayleigh waves based on coordinate transformation. Rayleigh waves are mechanical waves that propagate along the free surface of semi-infinite media. When they result from earthquake events, their control is of major interest in civil engineering for structure and infrastructure seismic protection. Under time-harmonic regime they are governed by a Navier elastodynamic equation that retains its form for an in-plane arbitrary coordinate transformation by assuming identical displacements in both the original and transformed media (Cosserat gauge) [1]. This is in contrast with the case of Love waves, where the Navier elastodynamic equation is always form invariant [2]. In particular, we apply transformation elastodynamics to derive the required mechanical properties for in-plane carpet cloak. However, the elasticity tensor of the transformed domain has now lost its minor symmetries, which makes it difficult to realize with common materials. To recover those symmetries, a symmetrization process is being employed by using the arithmetic mean. In this study, we compare the performance or triangular and circular cloaks with symmetric and non-symmetric elasticity tensors to demonstrate the effectiveness of the symmetrization technique via time-harmonic simulations and dispersive analyses. The approach presented herein could accelerate the design of efficient broadband elastic metamaterial cloaks for surface waves.

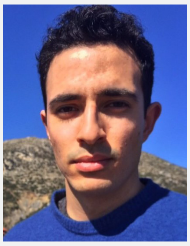
Zinon Chatzopoulos was born in Athens, Greece in 1995. He graduated from the School of Civil Engineering at the National Technical University of Athens (NTUA) in July 2019 (5-year Diploma), where he defended his Thesis in the field of Computational Mechanics, including Boundary and Finite Element Techniques for the local Buckling Analysis of Beams, under the supervision of Prof. Evangelos Sapountzakis. During his undergraduate studies, he co-authored and presented two papers at national and international conferences. He has also interned with G. Papamichail Mitakidi & Partners Architectural Design Office, based in Psychico, Athens. From 2020, he is a PhD candidate at the University of Bologna under the supervision of Prof. Marzani and Prof. Palermo and a member of the INSPIRE project as an early-stage researcher. His research pertains to the conception and design of a novel device, termed elastic cloak, which can protect structures from surface waves, by smoothly detouring the waves around it, without any scattering effect or loss of energy.

Thursday 25/05, 14:30 – 15:00

Could dynamic Struture-Soil-Structure Interaction (SSSI) be used to enhance Seismic Resilience of structures?
The case of a Nuclear Power Plant

by Constantinos Kanellopoulos

Inspired by the working principle of Seismic Resonant Metamaterials (SRM) as seismic protection devices for structures (i.e., the out-of-phase oscillation of the resonating masses with respect to the soil at targeted frequencies of interest), the idea of exploiting the dynamic interaction between neighbouring structures to their own benefit was born. With that in mind, and with the ever-increasing demand in the Nuclear industry for more realistic models that consider SSSI effects, a highly sophisticated finite element model of a Nuclear Power Plant, consisting of the main Reactor building that is surrounded by an Auxiliary building, is created. It is shown, that the presence of the neighbouring Auxiliary building can significantly modify the response of the Reactor building. For frequencies close to the resonant one of the Auxiliary building, a remarkable decrease in the spectral accelerations is observed when the presence of the latter is considered, while a small amplification takes place for lower frequencies. This comes as no coincidence and clearly resembles the protective behaviour of SRM. In other words, if properly designed, the Auxiliary building could provide seismic protection to the Reactor building at targeted frequencies. Finally, the importance of increasing the modeling sophistication for such important structures is highlighted; that is, engineers should be able to take into account in their models the effect of complex phenomena, such as Structure-Soil-Structure interaction, nonlinear interfaces, and nonlinear soil, that are usually neglected in practice. As this study shows, ignoring such phenomena could lead to erroneous results, that are not always conservative.



Constantinos obtained his diploma in Civil Engineering from the National Technical University of Athens (2017), with specialization in the fields of earthquake engineering and dynamic soil-structure interaction. In his diploma thesis, he studied the linear and nonlinear dynamic interaction between pile foundations and soil using the finite element method. After finishing with his military duties in August 2018, he started working as a research assistant in the group of Prof. G. Gazetas extending his research in pile groups and undertaking in parallel several projects relative to the dynamic soil-structure interaction field. Constantinos joined the Chair of Structural Dynamics and Earthquake Engineering at ETH Zürich in 2019 as a PhD candidate under the supervision of Prof. Dr. Bozidar Stojadinovic. His research lies within the “INSPIRE” ITN Marie Skłodowska-Curie research programme, working on seismic resonant metamaterials for the seismic protection of structures and communities (Meta-Cities).

Thursday 25/05, 15:30 – 16:00

Dynamics and instability of flexible structures with sliding constraints

by Panagiotis Koutsogiannakis

Although instabilities and large oscillations are traditionally considered as conditions to be avoided in structures, a new design philosophy based on their exploitation towards the achievement of innovative mechanical features has been initiated in the last decade. In this spirit, instabilities are exploited towards the development of systems that can yield designed responses in the post-critical state. Further, the presence of oscillating constraints may allow for a stabilization of the dynamic response. These subjects entail a rich number of phenomena due to the non-linearity, so that the study of such mechanical systems becomes particularly complex, from both points of view of the mechanical modeling and of the computational tools.

Two elastic structures are studied. The first consists of a flexible and extensible rod that is clamped at one end and onstrained to slide along a given profile at the other. This feature allows one to study the effect of the axial stiffness of the rod on the tensile buckling of the system and on the compressive restabilization. A very interesting effect is that in a region of parameters double restabilization is found to occur, involving four critical compressive loads. Also, the mechanical system is shown to work as a novel force limiter that does not depend on sacrificial mechanical elements. Further, it is shown that the system can be designed to be multi-stable and suitable for integration in metamaterials.

The second analyzed structure is a flexible but inextensible rod that is partially inserted into a movable rigid sliding sleeve which is kept vertical in a gravitational field. The system is analytically solved and numerically and experimentally investigated, when a horizontal sinusoidal input is prescribed at the sliding sleeve. In order to model the system, novel computational tools are developed, implementing the fully nonlinear inextensibility and kinematic constraints. It is shown that the mathematical model of the system agrees with the experimental data. Further, a study of the inclusion of dissipative terms is developed, to show that a steady motion of the rod can be accomplished by tuning the amplitude or the frequency of the sliding sleeve motion, in contrast with the situation in which a complete injection of the rod inside the sleeve occurs. A special discovery is that by slowly decreasing the frequency of the sleeve motion, the length of the rod outside the sleeve can be increased significantly, paving the way to control the rod's end trajectory through frequency modulation.

Panagiotis is a Post-doctoral researcher at the University of Trento, Italy, in the Solid and Structural Mechanics Group of the Department of Civil, Environmental and Mechanical Engineering. In the past, from 2019 to 2022, he participated in the INSPIRE ITN project funded by the Horizon 2020 framework programme, for the purposes of obtaining his PhD in structural mechanics. In 2019 he got his Diploma in Naval Architecture and Marine Engineering from the National Technical University of Athens (NTUA). His diploma thesis was in the field of GPU Acceleration of Numerical Methods for Lifting Flows. During his undergraduate studies, he participated in the internship programme of DNV-GL, where he focused on the coupling of Simulation Platforms for the solution of complex thermodynamic processes found in the maritime industry. During his last year at NTUA, he participated at the Monaco Solar & Energy Boat Challenge (MCSEBC) with the OCEANOS NTUA team, where his responsibility was the optimization of the propulsion system of the team's boat.

Thursday 25/05, 16:00 – 16:30

Numerical Analysis and Experimental Testing of the Extended KDamper: a Novel Dynamic Negative-Stiffness Absorber

by Antonis Mantakas

Recently, researchers have proposed an innovative negative stiffness-based vibration control concept, namely the KDamper absorber. The envisaged mechanism comprises a combination of appropriate stiffness, damping and mass elements, including a negative stiffness element. In this lecture, the mathematical framework of the system is presented along with design and optimization algorithms. These take into consideration the application of interest and geometrical and manufacturing limitations, regarding the vibration control components, including the realization of the negative stiffness mechanics. The KDamper is numerically and analytically implemented as a vibration control concept for seismic protection of buildings and results indicated its beneficial effect towards vibration attenuation. An experimental set-up of the proposed mechanism is designed by adopting an optimization procedure and tested under horizontal harmonic and seismic shaking. Results highlight the vibration control properties of the proposed system and validate previous numerical and analytical studies. The experimental device serves as a proof of concept of the KDamper absorber and showcases its advantages as well as application limitations that should be considered in future research

Antonis (ESR07) was born in Athens, Greece in 1991. He graduated from the School of Civil Engineering of the National Technical University of Athens (NTUA) where he defended his thesis in the field of SoilStructure Interaction and Geotechnical Earthquake Engineering. He received a Master's degree from Imperial College, London in the field of Soil Mechanics and Business Management with an overall classification of a strong distinction. Following his studies, Antonis joined Ramboll UK, a leading engineering consulting firm, at the position of geotechnical engineer. He focused on the design of piledraft foundations of high-rise buildings and offshore wind farms both in the United Kingdom and Denmark. Earlier in his career, he worked with Grid Engineers and the NTUA, conducting research in the field of soil dynamics and geotechnical engineering. Currently, Antonis is a Marie Skłodowska-Curie fellow and is pursuing a PhD at the School of Civil Engineering of the NTUA in the field of earthquake engineering and metamaterials. His main research focus is the development and testing of innovative vibration control devices that harness the beneficial properties of negative stiffness elements.

Thursday 25/05, 16:30 – 17:00

Friday

Morning Sessions

How digital technologies can enhance civil infrastructure sustainability and resilience

by Stergios Mitoulis

We live in a world that is increasingly interconnected and digital technologies play an important role in this. This gives us, the engineers, the unique opportunity to positively transform and establish the way we manage civil infrastructure, spanning from roads, railways to energy assets, networks and other hard assets using the plethora of openly available data. We need to do this in a way that costs less, respects the environment, delivers solutions toward combating climate change and makes people feel safer and happier. The challenge yet remains, as resources are diminishing and decision-making in many occasions is myopic, in the sense that short-termism prevent us from delivering benefits for future-proof infrastructure to deliver a more sustainable world. What is more, we have data available that can help us make informed decisions which remain hugely unexploited. This lecture hopes to contribute towards more sustainable and resilient infrastructure systems using digital data. It will focus on published research, methods, case studies and results for case studies on transport infrastructure, but will also include concepts and rationales that were developed for the 10 ongoing research projects, currently evolving into frameworks and recommendations for policy.

Stergios is the leader of the infrastructuResilience and bridgeUkraine research initiatives. Stergios' has a sustained record of grant-winning with more than €4.1 million of funding which he received from Horizon Europe and UK research funders. He led and won recently a €1.65 million HORIZON project ReCharged (ID: 101086413), and is leading the pilots of the € 2.5 million HORIZON project RISKADAPT (ID: 101093939). Over the last ten years, he has supervised and co-supervised more than 15 doctoral and postdoctoral researchers, including acting as mentor to junior colleagues and Ukrainian professors, who he supports with British Academy awards. He has published extensively with a publication record exceeding 170 papers in leading scientific journals and conferences. Stergios is trained as a bridge engineer. Through his career his expertise evolved and currently lies in the areas of resilience, sustainability and digitalisation of critical infrastructure. He has served as an evaluator for the European Research Council and UK research funders. He is a member of Eurocodes committees and UK delegate of the BSI. He is editor to Q1 journals. He has an extensive presence in the news of leading news agencies, including the BBC, Sky News. In 2022 Stergios won the Thorpe Medal of the European Council on Computing in Construction.

Friday 26/05, 09:00 – 09:30

Surface waves in resonant metamaterials: numerical design and experimental validation

by Farhad Zeighami

The design of locally resonant metamaterials to control the propagation of surface waves is an emerging research topic that has found multiple engineering applications during the last decade in different frequency ranges, from surface acoustic waves (SAW) devices to seismic wave barriers.

While previous studies in the literature have been limited to the design of locally resonant metasurfaces, ultra-thin boundary conditions realized by resonant interfaces or structures attached to the free surface of elastic waveguides, in this study, we go beyond this simplified assumption and investigate surface wave propagation in thick resonant layers. In order to tackle this problem, a numerical model has been developed exploiting the wave finite element method to design a resonant layer with a pre-defined thickness coupled to a non-resonant half-space. Then, a small-scale prototype was manufactured and tested via tabletop experiments to verify the outcomes of numerical analysis. In the experimental test setup, the resonant layer is constituted by a cluster of periodically arranged resonators distributed along the depth of the host medium (PVC material). The resonator is fabricated by a concentric rigid mass (steel material) attached to the host material via four elastic connectors.

In this presentation, the analytical approach to investigate Rayleigh-type surface wave propagation in thick resonant metamaterials will be briefly introduced, and then the outcomes of the experimental campaign will be presented. In particular, the observation of a low-frequency band gap in the spectrum of the surface waves and the cause of its emergence will be explained. In addition, the relationship between the resonant layer's thickness, the band-stop frequency width, and the magnitude of surface wave attenuation will be discussed. Finally, the filtering properties of thick resonant metamaterials and their possible future applications will be demonstrated.

Farhad Zeighami is a junior assistant professor of Structural Mechanics at the Department of Civil, Chemical, Environmental, and Materials Engineering (DICAM), University of Bologna, Italy.

He received his BSc degree in Civil Engineering from Arak University in 2011 and his MSc in Civil Engineering course (curriculum in structural engineering) from the University of Bologna in 2016. He obtained his Ph.D. in the Structural and Environmental Health Monitoring and Management course at the University of Bologna in 2021 with a thesis on "Resonant metamaterials for the control of Rayleigh waves." He continued his research as a Postdoctoral research fellow in 2021 and 2022 at the same department. Recently, he has been awarded a 3-year Marie Skłodowska-Curie Postdoctoral Fellowship for the REMoTIon project under the HORIZON-MSCA-2022-PF call.

Throughout his research, he hopes to contribute to designing, analyzing, and testing resonant metamaterials to manipulate the propagation of elastic waves across different frequency ranges. In particular, his current project aims to design locally resonant metamaterials for ground-borne vibration mitigation.

Friday 26/05, 9:30 – 10:00

State of the art of seismic isolation in Italy

by Maria Gabriella Castellano

Seismic isolation is used in Italy since the 1970s, first mainly in bridges and viaducts, then in buildings as well. Its use increased significantly in the last 20 years. The state of the art of applications is presented, with particular focus in buildings. In Italy, seismic isolation of buildings is not anymore limited to strategic or public buildings; it is continuously increasing for residential buildings as well, in particular in areas with high seismicity, in which the additional cost of isolators is compensated by the savings in the superstructure, and thus the global construction cost could be the same or lower of that of a conventional structure, but with much higher performance. Amongst a total of about 900 seismically isolated buildings in Italy until summer 2022, almost one half are residential buildings. Seismic retrofit of existing buildings with seismic isolation became relatively common after the 2009 L'Aquila earthquake, initially on buildings strongly damaged by the earthquake. Recently, retrofit with seismic isolation is continuosly increasing, even in areas not recently affected by earthquakes. Now the Italian buildings retrofitted with seismic isolation are about 1/3 of the total number of seismically isolated buildings.

M.Gabriella Castellano is a Civil Engineer with about 30 years experience in passive control of the seismic response of structures through seismic isolation and supplemental energy dissipation.
After the PhD in Structural Engineering, in which she studied elastomeric isolators, in 1996 joined the R&D Department of FIP Industriale, that in 2018 became FIP MEC. She has been involved in many research projects, aimed at developing anti-seismic devices for different types of structures, from petrochemical plants or nuclear power plants, to monumental buildings, as well as for non-structural elements (e.g. art objects).
Since December 2020, she joined FIP MEC Academy, acting now as a consultant to structural engineers for the design of both new and existing structures with seismic isolation and/or energy dissipation devices, and giving regular lectures to engineers, architects as well as students.

Friday 26/05, 10:00 – 10:30

A few observations from the M 7.8 earthquake in Turkey

by George Gazetas

A brief overview of seismological features of the event will be followed by analysis of some recorded ground motions, observations of fault rupture outcropping induced failures, and by preliminary findings regarding the distribution of damage in Antakya.

George Gazetas has served as Professor of Geotechnical Engineering at the National Technical University of Athens (Greece) for more than 30 years, following an academic career in USA. His research interests have focused on Soil Dynamics, Earthquake Geotechnical Engineering, and Soil–Structure Interaction. Much of his research was inspired by observations after destructive earthquakes. An active writer and teacher, he has been a consultant on geotechnical problems and participated in code drafting committees. Recipient of several awards (from the American Society of Civil Engineers, the Institution of Civil Engineers, the International Society of Soil Mechanics & Geotechnical Engineering, as well as from Institutions in Greece, India, and Japan), he has delivered prestigious lectures, including the “Coulomb”, “Ishihara”, “Kenneth Lee”, and “Michele Maugeri” Lectures. In 2015 he received the “Excellence in University Teaching in Greece Award”. He was honored as the 59th Rankine Lecturer, 2019, in London, and as a GeoLegend by ASCE’s Geo Institute in 2022.

Friday 26/05, 11:00 – 11:30

Nonlinear Response of Existing Bridges on Pilegroups: Numerical and Physical Modelling

by Ioannis Anastasopoulos

The vast majority of existing bridges were built before the 90's, without any or just basic seismic design. Pile group strengthening can be a challenging, costly, and time-consuming operation, calling for optimised solutions. The lecture will look into the behaviour of pile groups under combined Vertical, Horizontal and Moment (VHM) loading, combining 3D Finite Element (FE) and centrifuge modelling. Initially, a proof-of-concept study is conducted, inspired by the recent widening of a Swiss bridge. According to conventional design, the existing pile group needs retrofit to accommodate the increased seismic loads due to widening. An unconventional "do-nothing" approach is explored (maintaining the existing foundation), exploiting nonlinear soil response. Such an approach requires improved design methods and better definition of the ultimate capacity of pile groups under combined loading. In this context, after developing a database of Swiss bridges and identifying pile group typologies encountered in practice, a fundamental yet representative 2 x 1 bored pile group is tested at the ETH Zurich (ETHZ) Geotechnical Centrifuge Centre (GCC). Four experimental setups are developed and verified for vertical, pushover, combined, and vibration testing. After determining the bearing capacity under vertical loading, pushover loading is employed to measure the moment capacity (M_{ult}) of a lightly- and a heavily-loaded (widening) pile group. In contrast to intuitive expectations, the heavily-loaded system mobilises larger M_{ult}. Combined loading is performed to derive experimental failure envelopes, confirming their tendency to expand with increasing vertical load. The centrifuge results are used for FE model validation. The numerical technique is upgraded to account for nonlinear soil–pile interaction, using hypoplasticity for sand and appropriate modelling of interfaces and pile response. The transition to prototype scale accounts for scale effects, and employs the Concrete Damaged Plasticity (CDP) model for proper simulation of the reinforced concrete (RC) piles. The latter is a key advancement, accounting for the axial load dependency of bending moment capacity. The problem is studied parametrically, deriving failure envelopes in function of vertical loading, confirming the increases of pile group capacity with increasing vertical load. Finally, the Limit Equilibrium method is used to derive closed-form analytical failure envelopes, providing a useful design tool for engineering practice. The latter are verified against the FE analysis results.

Ioannis Anastasopoulos has been Full Professor and Chair of Geotechnical Engineering at ETH Zurich since 2016. He specializes in geotechnical earthquake engineering and soil–structure interaction, combining numerical with experimental methods. His research interests include resilient seismic design and preparedness, innovative seismic hazard mitigation, sustainable geotechnical construction, design against faulting, foundations for renewable energy, tsunamis and their effects on coastal infrastructure, scouring of bridge foundations, soil liquefaction and structure–soil–structure interaction. He is the inaugural recipient of the Young Researcher Award of ISSMGE in Geotechnical Earthquake Engineering, and winner of the 2012 Shamsher Prakash Research Award. He has been involved as a consultant in a variety of projects in Europe, the US and the Middle East. His consulting work ranges from the design of pile-rafts of tall buildings/towers, special seismic design and retrofit of existing bridges, metro stations and tunnels, to harbour quay walls, and special design against faulting. He has served as National Delegate-Expert for Switzerland for Eurocode 7 and as a member of the SIA 267 Commission. Moreover, he is actively engaged in the organization of international conferences, specialized workshops and training courses, fostering knowledge transfer between the academia and the industry. He serves as Associate Editor of Soil Dynamics and Earthquake Engineering, Journal of Earthquake Engineering, the International Journal of Physical Modelling in Geotechnics, and Frontiers in Built Environment, and has served in the panel of Géotechnique and ICE Geotechnical Engineering. He is a member of the Board of Directors of the International Association for Earthquake Engineering (IAEE), and Chair of ISSMGE TC104 on Physical Modelling in Geotechnics.

Friday 26/05, 11:30 – 12:00

Augmented Structural Twins: At the Nexus of Data & Models

by Eleni Chatzi

Modern engineering structures form complex - often interconnected - assemblies that operate under highly varying loads and adverse environments. To ensure a resource-efficient and resilient operation of such systems, it is imperative to understand their performance as-is; a task which can be effectuated through Structural Health Monitoring (SHM). SHM comprises a hierarchy across levels of increasing complexity aiming to i) detect, ii) localize and iii) quantify damage, and iv) finally offer a prognosis over the system's residual life. When considering higher levels in this hierarchy, including damage assessment and even performance prognosis, purely data-driven methods are found to be lacking. For higher-level SHM tasks, or for furnishing a digital twin of a monitored structure, it is necessary to integrate the knowledge stemming from physics-based representations, relying on the underlying mechanics. This talk discusses implementation of such a hybrid approach to SHM for tackling the aforementioned challenges with particular focus on applications for wind turbine structures.

Eleni Chatzi is an Associate Professor and Chair of Structural Mechanics and Monitoring at the Department of Civil, Environmental and Geomatic Engineering of ETH Zurich, Switzerland. Her research interests include the fields of Structural Health Monitoring (SHM) and data-driven assessment for engineered systems. She has authored more than 300 papers in peer-reviewed journals and conference proceedings, and further serves as an editor for international journals in the domains of Dynamics and SHM. She led the recently completed ERC Starting Grant WINDMIL on the topic of "Smart Monitoring, Inspection and Life-Cycle Assessment of Wind Turbines". Her work in the domain of self-aware infrastructure was recognized with the 2020 Walter L. Huber Research prize, awarded by the American Society of Civil Engineers (ASCE).

Friday 26/05, 12:00 – 12:30

Friday

Afternoon Sessions

Kinematic response of pile group and piled raft foundations to distant harmonic loads

by Christos Vrettos

Results from finite-element analyses of pile groups and piled rafts excited by a stationary harmonic vertical point load acting on the soil surface at a given distance are presented. Various typical pile group layouts are examined. The soil is modelled as a linear viscoelastic continuum with a constant shear velocity. A wide range of frequencies from 8 to 64 Hz is investigated. Focus is placed on the resulting vertical response. In the frame of metamaterials, the influence of the pile row number in the direction of wave propagation is explored in terms of vibration reduction. Subsequently, the case of a harmonic load travelling with a constant speed parallel to the pile group is investigated. Most importantly, it is revealed that a stationary load located on the travel axis at minimum distance from the pile group is a good approximation for the moving load scenario. This applies in most cases of practical interest.

Dr. Christos Vrettos is Professor of Soil Mechanics and Foundation Engineering at the Rhineland-Palatinate Technical University in Kaiserslautern, Germany. He holds Dipl.-Ing. and Dr.-Ing. degrees from the University of Karlsruhe, and a habilitation from the Technical University of Berlin. He spent several years in the construction industry and geotechnical consulting. His expertise covers soil mechanics and foundation engineering, soil dynamics and geotechnical earthquake engineering, vibration protection, numerical methods in geomechanics, advanced soil mechanical testing, extra-terrestrial soil mechanics, and terramechanics. Notable projects include deep excavations and high rise building foundations in urban areas, tailing dams, immersed tunnels, and ground improvement. He is member of several DIN and European code committees on geotechnical and on seismic design topics. He is author of numerous publications, reviewer for major journals and editor-in-chief of “geotechnik”.

Friday 26/05, 13:30 – 14:00

Mechanical switching of SAWs and identification of nonlinear metamaterials

by Fabrizio Aloschi

This talk presents a novel device for controlling the flow of mechanical waves. The proposed device uses outer beams to switch the propagation of surface acoustic waves ON and OFF, by utilizing postbuckling softening to cancel bandgaps. The switching mechanism is achieved through the activation of nonlinearity, without the need for external magnetic fields or logic gates. The wave propagation along the surface, and the mechanical switching, are explained through experimental dispersion curve reconstruction. This talk also introduces a novel method to identify the dispersion curves of nonlinear periodic systems. These approaches offer promising avenues for the design and implementation of devices based on nonlinear periodic materials.

Fabrizio recently completed his PhD in the field of civil/mechanical engineering from the University of Trento. His thesis titled "Analysis of Nonlinear Metamaterials and Metastructures for Mitigation and Control of Elastic Waves" reflects his passion for wave propagation and nonlinear systems. During his PhD, Fabrizio mostly focused on the identification of periodic systems, and his research may have positive implications for the development of new materials and structures with improved properties, and the mitigation and control of elastic waves. In five months spent at Caltech, he worked on developing a device that enables the control of surface acoustic waves through buckled beams.

Friday 26/05, 14:00 – 14:30

A meta-material layout for blast protection of on-earth pipes against surface explosion

by Miltiadis Kontogeorgos

This study is coming as follow-up of authors' previous published work on the meta-material layouts and the blast protection that they can provide to buried steel pipes towards surface explosions. The current work is stepping forward and is presenting the beneficial presence and exploitation of meta-materials in favour of the on-earth pipelines' protection towards surface explosion, via analytical and numerical calculations. The band-gaps of the meta-material layout are calculated analytically based on the periodic materials' theory, while numerical calculations included various blast scenarios of different explosive quantities for a more accurate depiction of layout's protective abilities.

Miltos was born in Athens, Greece in 1993. He graduated from the department of Civil Engineering of the National Technical University of Athens where he specialized in soil-structure interaction and earthquake engineering. In his diploma thesis he investigated the effect of accounting for soil plasticity in the calculation of seismic forces that apply in structures founded on rigid caissons ultimately aiming to demonstrate the virtues of a new anti-seismic design philosophy. Now he is conducting his PhD in the RINA Consulting S.p.A. in collaboration with the National Technical University of Athens as member of the INSPIRE MSCA research program, in the field of meta-materials and their innovative applications and concepts in the geotechnical engineering.

Friday 26/05, 14:30 – 15:00

Periodic barriers to attenuate vibration in the railway environment

by Slimane Ouakka

The recent positive growth of railway transport pushed by its sustainability made it one of the most eco-friendly means of transportation. On the other hand, the main drawback of this means of transportation - the generated induced vibration - continues to be a source of concern in urban areas which negatively affects the daily life of the residents. Therefore there is a need to find a way to attenuate the vibration wave propagation in the nearby urban areas. Considering the high costs of field measurement and the parametric investigation needed, the problem has to be tackled numerically in order to have a preliminary evaluation of future mitigation measures.

Therefore, a presentation of a numerical two-step approach to reproduce the railway environment is presented, giving the details of the needed assumption in order to have a correct representation of the railway environment. Following the case study of the T2000 LRV (Light Rail Vehicle) tram operating in Brussels will be considered and the attenuation level of seismic metamaterial will be presented by considering both embedded and resonant metamaterial, by conducting a parametric investigation. Finally, some insights are given into the use of metamaterials as mitigation measures for railway-induced vibration in order to understand and evaluate the potential of this novel concept and its benefits.

Slimane graduated from the University of Bologna from the faculty of Engineering. Following his master, he spent 6 months as a Visiting Researcher at the Wind Energy Center at the University of Massachusetts. After that, he joined Limitstate ltd in Sheffield (UK), a company developing software for Civil engineering usage. Since November 2019 he embarked on the INSPIRE project at the University of Mons (Belgium), as ESR13 on the topic of meta-material concepts in rail with a focus on the implementation of new mitigation measures toward the induced vibration generated by rail traffic.

Friday 26/05, 15:30 – 16:00

Numerical and experimental investigation of DDA enhanced metamaterials

by Moris Kalderon

Locally resonant metamaterials (LRMs), with periodic elements that exhibit local resonance, have been recently investigated by numerous researchers as a means to pursue vibration attenuation and wave manipulation. These structures are able to generate bandgaps in specific frequency ranges depending on their mass, stiffness and geometrical characteristics; however, they present certain limitations when bandgaps in the low-frequency domain are sought since they require heavy oscillating masses. This research work harnesses the potency of a novel dynamic directional amplifier, namely the DDA, that is introduced as a means to artificially increase the inertia of an oscillating mass. The DDA is realized by imposing kinematic constraints to the degrees of freedom (DoFs) of the oscillator, hence inertia is increased by coupling the horizontal and vertical motion and forcing the model to move along a circumference. In this lecture, the DDA is applied on scaled LRM and phononic structures, both assembled using LEGO® components. The dynamic response of the proposed metamaterials is examined using experimental and numerical methods, while results indicate the beneficial role of the device and DDA mechanism, hence placing the concept as a compelling alternative to existing vibration control technologies.

Moris was born in Larisa, Greece in 1991. He obtained his diploma in Civil Engineering from the National Technical University of Athens in 2015, in the discipline of Structural and Geotechnical Engineering. After his graduation, Moris gained construction experience working for Archirodon NV as a Site Engineer for the New Double High-Speed Railway project in Greece. In 2017 he received a Master's degree from Imperial College, London in the field of Soil Mechanics. After completing the program, Moris joined WSP UK, a top-tier engineering consulting firm, where he focused on the design of railway bridge foundations for major UK infrastructure projects. Currently, Moris is a Marie Skłodowska-Curie fellow and recently he completed his PhD at the School of Mechanical Engineering of the NTUA in the field of acoustic metamaterials. His research focus is the development and testing of innovative vibration control devices, acoustic wave mitigation and earthquake engineering.

Friday 26/05, 16:00 – 16:30

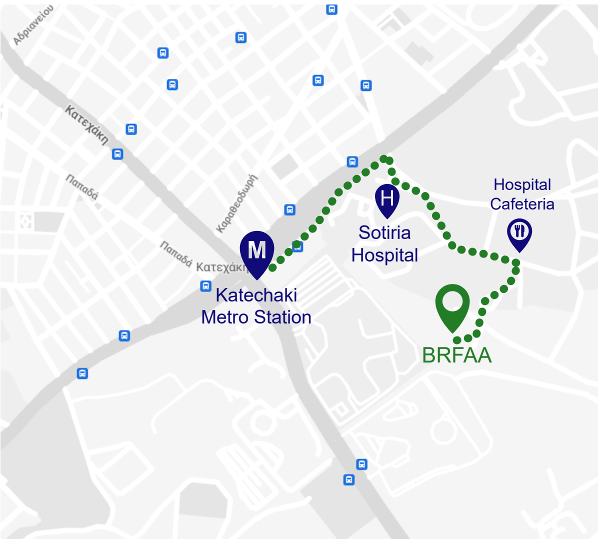
The Venue

Biomedical Research Foundation Academy of Athens

The BRFAA Auditorium is a state-of-the art facility that seats 270 delegates. The Auditorium is surrounded by a beautiful courtyard which is ideal for break-out sessions during springtime. The reception area – located immediately outside the auditorium– will host the coffee-breaks and the INSPIRE dissemination kiosk for the demonstration of research prototypes. There is also a large outdoor parking area that is free for all participants.

How to get there

On foot from Katechaki station (approx. 20 min.)



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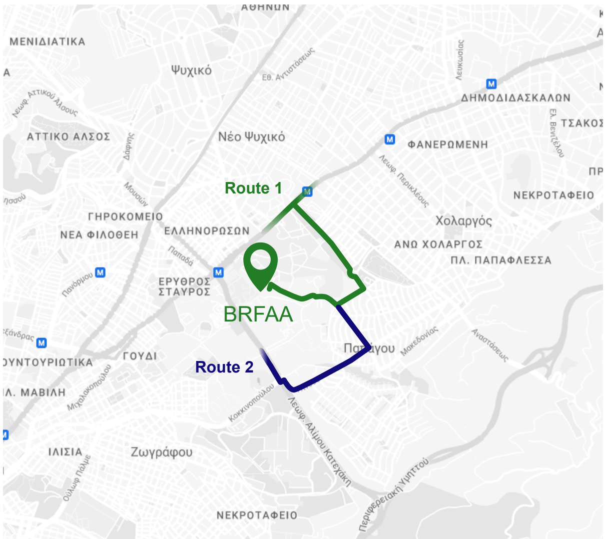

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