

**UNIVERSITATEA TEHNICĂ DE CONSTRUCȚII  
BUCUREȘTI**

**Dynamic Soil Properties and Seismic Risk Assessment of  
Structures**

**Habilitation Thesis - Summary**

Domeniul de doctorat: Inginerie civilă

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## SUMMARY

The principal objective of the research activities presented in this habilitation thesis, entitled “Dynamic Soil Properties and Seismic Risk Assessment of Structures”, is to develop advanced methodologies and tools for understanding, quantifying, and mitigating the seismic response of soils and structures in Romania. The work integrates fundamental geotechnical research with applied seismic risk studies, aiming to improve both national design practices and urban resilience strategies.

The thesis builds upon two major scientific and professional directions that have defined the author’s career over the past 25 years:

- Seismic Characterization of Soils — through laboratory, field, and analytical studies that establish reliable relationships between soil dynamic properties and seismic response.
- Seismic Risk Assessment of Structures — through the development of integrated hazard, vulnerability, and exposure models applied to urban areas and national-scale risk management.

These directions converge toward a unified vision: bridging experimental geotechnics, seismology, and structural reliability into a coherent framework for disaster risk reduction. The research is situated at the interface between engineering practice, scientific investigation, and public policy, contributing directly to Romania’s national strategy for seismic risk mitigation and to the alignment with European frameworks such as EPOS and Horizon Europe.

Dr. Eng. Cristian Vasile Arion graduated from the Technical University of Civil Engineering Bucharest (UTCB) in 1996, obtaining his Bachelor’s and Master’s degrees in Civil and Geotechnical Engineering, followed by a Ph.D. in Civil Engineering (2003) with a dissertation on “Seismic Zonation Considering Site Conditions and Seismic Sources Specific to Romania.” After graduation, he began his professional career as a structural design engineer, contributing to the seismic design of major civil projects including the Marriott Grand Hotel, the National Stadium, and the Tour Place de la Victoire in Bucharest. His practical experience provided a strong foundation for later academic and research excellence. Between 2002 and 2010, he served as Chief of Division for Technical Experimentation on Soils and Structures at the National Center for Seismic Risk Reduction (NCSRR), where he coordinated experimental studies under the JICA Technical Cooperation Project (Japan International Cooperation Agency). This collaboration introduced modern seismic and geotechnical testing technologies to Romania and led to the establishment of one of the country’s first laboratories for dynamic soil testing. His international experience includes professional training and research at:

- International Institute of Seismology and Earthquake Engineering (IISEE), Tsukuba, Japan;
- Tokyo University (Towhata Laboratory);
- Waseda University (Hamada Laboratory);
- CEDEX, Madrid, under the TEMPUS program;
- Karlsruhe University (Germany) within the SFB 461 program.

Since 2015, he has been Associate Professor at UTCB, teaching Structural Reliability and Risk Analysis, Seismology and Earthquake Engineering, and Urban Seismic Risk, and actively mentoring master's and doctoral students.

Over more than two decades of continuous research, Dr. Arion has produced a significant scientific portfolio encompassing experimental soil mechanics, numerical modelling, seismic hazard analysis, and risk management. His work is both foundational and applied, directly influencing national design codes and disaster management policies.

The Research Direction I – Seismic Characterization of Soils forms the core of the habilitation thesis. It addresses how the dynamic behavior of soils—their stiffness, damping, and strain dependence—affects seismic site response and the performance of structures during earthquakes. The selected contributions enabled the accurate estimation of site amplification factors, refined local seismic hazard models, and established a methodological standard for future geotechnical investigations in Romania:

- Implementation of Dynamic Laboratory Testing in Romania:

Under the JICA cooperation, Dr. Arion introduced cyclic triaxial compression, ultrasonic pulse, and bender element techniques for measuring the shear modulus ( $G$ ) and damping ratio ( $h$ ) of soils at various strain levels. This was the first systematic attempt in Romania to establish  $G$ - $\gamma$  and  $h$ - $\gamma$  curves for local soils.

- Integration of Field Seismic Methods:

He implemented downhole, crosshole, and MASW surveys for in-situ evaluation of shear-wave velocity ( $V_s$ ), ensuring consistency between laboratory and field data. These studies allowed for the calibration of empirical  $V_s$ -SPT-plasticity correlations for Romanian soil types.

- Creation of National Databases and the SETTING Platform:

The experimental results were integrated into a national geotechnical database—SETTING (2021–2023)—a digital platform combining  $V_s$  profiles, GNSS, and seismic data, forming Romania's contribution to the European Plate Observing System (EPOS).

- Development of the First  $V_{s30}$  Microzonation Map for Bucharest:

Combining borehole data down to 145 m with MASW profiles, he produced the first comprehensive  $V_{s30}$  map for the capital city, essential for the classification of soil categories in Eurocode 8 and for site-specific hazard assessment.

- Modernization of Experimental Infrastructure:

He coordinated upgrades to the Seiken Dynamic Triaxial System at the Seismic Risk Assessment Research Center (CCERS), introducing 16-bit signal acquisition, new load cells, and advanced data-processing algorithms to minimize measurement error at very low strains.

The Research Direction II – Seismic Risk Assessment of Structures integrates hazard, vulnerability, and exposure data into a comprehensive seismic risk framework. Major Achievements:

- Development of the ROSERIS GIS Platform:

Dr. Arion co-developed ROSERIS, Romania's first geographic information system for seismic risk assessment, merging building inventories, hazard maps, and loss models. It applies the HAZUS (FEMA) methodology, adapted to local building typologies, to generate probabilistic damage scenarios and economic loss estimates.

- Participation in European and National Research Projects:

He contributed to numerous international collaborations, including: RISK-UE (FP5) – European Earthquake Risk Scenarios; PROHITECH (FP6) – Protection of Historical Structures; COST Action C26 – Resilient Urban Habitats; RO-RISK (2016–2017) – National Risk Assessment of Romania; ANDROID (Erasmus) – Disaster Resilience Education Network.

- Adaptation of Fragility Curves and Vulnerability Functions:

He developed new fragility models for reinforced concrete and masonry buildings, based on empirical data from Romanian construction stock, contributing to the National Strategy for Seismic Risk Reduction (NSSRR, 2022).

- Urban-Scale Modelling and Decision Support:

The ROSERIS platform, combined with Copernicus and Digital Height Model datasets, allows real-time visualization of hazard exposure and supports emergency management, insurance analysis, and strategic planning.

- Societal Impact:

This work provides policymakers and engineers with actionable, quantitative information for prioritizing seismic retrofitting and urban planning.

The Research Direction III – Contributions to Codes and Standards, Dr. Arion's scientific expertise has been transferred into normative frameworks through active participation in national and regional standardization. Key Contributions:

- Co-author of Romanian Seismic Design Codes P100-1 (2006, 2013) and P100-3 for seismic evaluation and retrofitting.
- Co-author of CR 0 (Basis of Structural Design), CR 1-1-3 (Snow Loads), and CR 1-1-4 (Wind Loads).
- Author of Republic of Moldova National Annexes to Eurocodes EN 1990 and EN 1991, promoting harmonization within the Eurocode framework.

These activities reinforce the connection between experimental data, analytical modeling, and practical design regulations.

The Research Direction IV – Academic and Educational Achievements. As Associate Professor at UTCB, Dr. Arion combines research with academic leadership, teaching undergraduate and graduate courses such as Structural Reliability and Risk Analysis, Urban Seismic Risk, and Natural Hazards in Coastal Regions (EU-CONEXUS). He has supervised numerous MSc and PhD theses, focusing on applied research topics within national and European projects. His educational approach emphasizes interdisciplinary problem-solving, numerical modelling, and project-based learning, aligning with the evolving needs of civil engineering education. He has authored textbooks (over 140 works in journals, conference proceedings, and book chapters, books: 6 authored or co-authored volumes, Citation Metrics: h-index 13 (Google Scholar), 6 (Scopus), 5 (Web of Science).and lecture materials widely used in Romanian engineering programs, including:

- Seismic Motions – Examples of Application in Earthquake Engineering (2013);
- Evaluation of Vulnerability of Utilities and Essential Facilities (2017);
- Urban Seismic Risk Management Using GIS (2009).

The habilitation thesis defines a strategic roadmap for the next decade, aligning research with Romania's and Europe's resilience goals.

The Research Priorities:

- Integration of dynamic soil datasets into Eurocode 8 and national annexes.

- Expansion of SETTING and ROSERIS into interoperable multi-hazard platforms.
- Enhancement of experimental infrastructure at CCERS, including 3D soil–structure interaction facilities and digital instrumentation.
- Strengthening partnerships with engineering firms, government agencies, and international institutions for practical technology transfer.

#### Academic Development

- Introduction of new interdisciplinary courses (Digital Hazard Modeling, Advanced Geotechnical Earthquake Engineering).
- Active supervision of doctoral and postdoctoral researchers.
- Increased integration of simulation, AI-assisted modeling, and open data methodologies into teaching.

#### International Collaboration

- Continued cooperation with EPOS, UNESCO-IPRED, COST Actions, and Japanese and German research centers, promoting data harmonization, capacity building, and joint research.

#### Institutional and Societal Engagement

- Continued involvement in ASRO committees for standardization.
- Evaluation of research proposals for UEFISCDI and Horizon Europe.
- Organization of national conferences and thematic workshops at UTCB.
- Publication of technical manuals and public education materials on seismic safety.

The scientific and professional activity presented in this habilitation thesis demonstrates a coherent, long-term commitment to advancing earthquake engineering in Romania through innovation, data-driven research, and education.

#### Dr. Cristian V. Arion's work:

- Modernized the experimental infrastructure for soil dynamics and site response studies in Romania;
- Provided new analytical and empirical models for seismic design and risk assessment;
- Contributed directly to national codes and resilience strategies;
- Strengthened Romania's participation in European scientific networks;
- Trained a new generation of engineers and researchers equipped to address modern challenges in seismic safety.

The thesis thus confirms the author's scientific maturity, leadership, and vision for the future development of the field. His contributions represent a decisive step toward positioning UTCB as a regional center of excellence in earthquake engineering and geotechnical seismology, dedicated to proactive resilience, disaster preparedness, and the protection of human life and built heritage

#### Relevant Publications:

The list of 10 publications selected by the candidate, considered to be relevant for the professional achievements obtained by the candidate for the postdoctoral period, sustaining his activity presented in the Habilitation Thesis are listed below:

- 1.1 **Arion C.**, Lungu D, Vacareanu, R. 2009. Earthquake hazard and risk in Romania, p. 1437-1442. Protection of Historical Buildings, PROHITECH 09, 2009 Taylor and Francis Group, London, ISBN 978-0-415-55803-7.
- 1.2 **Arion C.**, Lungu D, Neagu C Calarasu E., 2009, Geotechnical in situ investigation for seismic design of buildings in Romania; *in Performance-Based Design in Earthquake Geotechnical Engineering* – Kokusho, Tsukamoto & Yoshimine (eds) © 2009 Taylor & Francis Group, London, p.1293-1300, ISBN 978-0-415-55614-9
- 1.3 Bala A., **Arion C.**, Aldea A., 2013. In situ borehole measurements and laboratory measurements as primary tools for the assessment of the seismic site effects, *Romanian Reports in Physics, Vol. 65, No. 1, P. 285–298, 2013; ISSN 1221-1451 43 822*
- 1.4 Văcăreanu, R., Demetriu, D., Lungu, D., Pavel, F., **Arion, C.**, Iancovici, M., Aldea, A., C., Neagu, C. (2014). Empirical ground motion model for Vrancea intermediate-depth seismic source. *Earthquakes and Structures. An International Journal*, Volume 6, Number 2, pp 141-161, DOI: 10.12989/eas.2014.6.2.127
- 1.5 **Arion C.**, Calarasu E., Neagu C., 2015. Evaluation of Bucharest soil liquefaction potential, *Mathematical Modelling in Civil Engineering*, volume 11, no.1, 5-12. Doi: 10.1515/mmce-2015-0005
- 1.6 Calarasu, E., **Arion, C.**, Neagu, C., (2016). Prediction of Site Characterization Based on Field Investigations and Empirical Correlations. In: Văcăreanu, R., Ionescu, C. (Eds) (2016). The 1940 Vrancea Earthquake. Issues, Insights and Lessons Learnt. Proceedings of the Symposium Commemorating 75 Years from November 10, 1940 Vrancea Earthquake, Springer Natural Hazards Book Series, p. 169-188, eBook ISBN 978-3-319-29844-3, Hardcover ISBN 978-3-319-29843-6, DOI 10.1007/978-3-319-29844-3\_11
- 1.7 Vacareanu, R., Pavel, F., Craciun, I., Coliba, V., **Arion, C.**, Aldea, A., Neagu, C., (2017). Risk-targeted maps for Romania. *J Seismol* (2017). <https://doi.org/10.1007/s10950-017-9713-x>
- 1.8 Pavel, F., Văcăreanu, R., Calotescu, I., Sandulescu, A.-M., **Arion, C.**, Neagu, C. (2017). Impact of spatial correlation of ground motions on seismic damage for residential buildings in Bucharest, Romania. *Natural Hazards*, DOI 10.1007/s11069-017-2814-6
- 1.9 **Cristian Arion**, Florin Pavel, Radu Vacareanu, Cristian Neagu, Mihail Iancovici, Viorel Popa and Ionuț Damian (2018) Seismic Risk Assessment of Romania. In: Vacareanu R., Ionescu C. (eds) *Seismic Hazard and Risk Assessment*. Springer Natural Hazards. Springer, Cham. [https://doi.org/10.1007/978-3-319-74724-8\\_17](https://doi.org/10.1007/978-3-319-74724-8_17)
- 1.10 Neagu C., **Arion C.**, Aldea A., Calarasu EA., Vacareanu R., Pavel F. (2018) Ground Types for Seismic Design in Romania. In: Vacareanu R., Ionescu C. (eds) *Seismic Hazard and Risk Assessment*. Springer Natural Hazards. Springer, Cham. [https://doi.org/10.1007/978-3-319-74724-8\\_11](https://doi.org/10.1007/978-3-319-74724-8_11)