GADRI Membership Application Form

Name of Institute:	Croatian Center for Earthquake Engineering (CCEE), Faculty of Civil Engineering University of Zagreb
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Institute Outline:

In Croatia, there is a long **tradition** of research in the field of earthquake engineering, but for decades we relied mainly on other regional centers (for example, IZIIS). After becoming an independent country (1991), most issues related to earthquake engineering were ignored (considering many other major problems), i.e. experts worked individually/scattered at universities all over Croatia, including in Zagreb. Experts and scientists from the **Faculty of Civil Engineering (FCE), University of Zagreb**, have participated for many years in various regional and international scientific projects, conferences and workshops on earthquake-related topics and are authors of numerous scientific papers published in regional and international journals. They have acquired their knowledge through participation in projects, training courses and workshops on disaster risk reduction, post-earthquake damage assessment and rescue team collaboration. They have expanded their field experience by participating in damage assessments after past devastating regional earthquakes and floods.

Earthquakes that struck Zagreb on March 22, 2020, and Sisak-Moslavina County on

December 28-29, 2020, were gamechanger. Faculty staff participated in all activities aimed at mitigating the consequences of the earthquakes and helping in the reconstruction and recovery of the affected areas and community. Their activities included:

i. organizing building inspections and leading relief efforts,
ii. developing a methodology and digital platform for assessing building damage and usability,
iii. conducting on-site training and education for engineers,
iv. establishing the "Croatian Center for Earthquake Engineering" platform for information and guidelines,
v. the publication of retrofitting manuals,
vi. the formation of a multidisciplinary working group for reconstruction planning and the development of regulations,
vii. cooperation with the World Bank on damage assessment and estimation of reconstruction costs for the Croatian Government and other initiatives.
viii. many others.

In order to provide basic information to professionals in the field during the process of damage assessment, to gather all the knowledge and experience of scientists and experts in the field of earthquake engineering and to build a strong network between them, an unofficial **platform called "Croatian Center for Earthquake Engineering"** (www.HCPI.hr) was established a few days after the earthquake in Zagreb in March 2020. This platform led to the establishment of a centers for earthquake engineering in Croatia. First, in early 2021, a new scientific research branch of the FCE called the Croatian Center for Earthquake Engineering (CCEE) was officially established with the great support of the Ministry of Spatial Planning, Construction and State Property, and the approval of the Ministry of Science and Education, which is also the main source of funding for the research projects and other activities of the CCEE. In October 2021, an association (NGO) named Croatian Center for Earthquake Engineering – Intervention Service (CCEE-IS) was established, which gathers all capacities/stakeholders at the state level (8 faculties, 5 chambers, 4 engineering associations) - under the Civil Protection Department of the Ministry of Interior. The idea of CCEE and CCEE-IS is a constructive cooperation between scientists, engineers, authorities, emergency services and citizens in order to achieve the main goals – preparedness and disaster risk reduction for the entire Croatian territory.

Although the CCEE research center was only **founded in 2021**, the research group's infrastructure has sufficient financial support and a strong global network within the scientific and professional community in the fields of earthquake engineering, seismic risk assessment, seismology and the design and retrofitting of existing

structures. As a branch of the Faculty of Civil Engineering, University of Zagreb, CCEE as a research center has the administrative support and available laboratory equipment of the Structural Testing Laboratory of the Department of Engineering Mechanics. After the 2020 earthquakes, establishment of a new laboratory started, more specialized for research in the field of earthquake engineering, and most key steps have already been taken.

Research Interests (areas of research disciplines, number of faculty members, etc.):
The CCEE research center consists of a committee of 20 members (full professors, associate professors and assistant professors), two researchers (currently one postdoctoral researcher and one PhD student) and 7 PhD students. The CCEE collaborates with numerous researchers from other departments of the FCE and other universities, practitioners, institutes in Europe and worldwide. The team members are researchers in the field of earthquake engineering and seismic risk assessment. They have participated in various research projects and have published numerous scientific and technical papers in globally recognized journals. The group actively cooperates with national and regional organizations and authorities, such as the Croatian Chamber of Civil Engineers, the Ministry of Interior (Civil Protection Department), and international foundations and organizations such as the Global Earthquake Model (GEM) Foundation, EFEHR (European Facilities for Earthquake Hazard and Risk) Consortium, the World Bank Group, etc.

Fig. 1. CCEE committee members (left) and PhD students and postdoctoral researchers with the leader of the CCEE (right)

Members of the CCEE research team have been at the forefront of seismic risk assessment in Croatia. They conducted a seismic risk assessment for the Republic of Croatia in 2014 in cooperation with the Ministry of Physical Planning, Construction, and State Assets and the Department for Civil Protection of the Ministry of Interior. The assessment was updated in 2018 and 2022, when the team again took the lead. Currently, CCEE and FCE, in cooperation with the Department of Emergency

Management of the City of Zagreb, are leading a project funded by the European Structural and Investment Funds entitled “Seismic Risk Assessment of the City of Zagreb”. The research group is also working on several professional projects for the structural design and seismic assessment of cultural heritage buildings and buildings of national interest, such as the Zagreb Cathedral, Croatian National Theatre building, Palace of Justice etc. There are many different activities because the center is recognized as a center of knowledge, for example the CCEE team has collaborated with the Department of Civil Protection in the project “Towards Disaster Risk Reduction" to set up a virtual laboratory – a truck trailer containing actuators for earthquake shaking simulation with visual effects.

To achieve **CCEE's main objectives** of earthquake risk reduction and the development of a resilient community in Croatia, the main activities, defined during the process of establishment of CCEE (2021), are:

- Research and development of scientific foundations in the field of earthquake engineering and seismic risk assessment, in particular in the field of detailed inspection of structures, structural performance of existing structures and cultural heritage, and design of structures of national interest.
- Laboratory and field tests related to earthquake engineering.
- Development of strategic plans and programs in the field of earthquake engineering.
- Activities in higher education in earthquake engineering, seismic risk reduction and various types of professional and scientific training for engineers and experts according to the state-of-the art research.
- Training in earthquake preparedness and earthquake engineering for engineers, intervention units, government officials, other public sector employees and industry personnel.
- Organization and implementation of post-earthquake building damage assessment and cooperation with emergency services.
- Development of a methodology for seismic certification, implementation and training for the issuance of seismic certificates.
- Activities aimed to develop, protect, maintain and analyze databases of buildings (exposure models), especially information on structural properties required for seismic risk assessment and strategic planning.

These activities are developing within the framework of an extensive research project called **”Research in the field of earthquake engineering”** financed by the government. In addition, **the CCEE has launched 8 scientific projects/activities**, covering different areas in the field of earthquake engineering: structural health monitoring, development of program packages and standards for out-of-plane mechanism

calculations according to Eurocode 1998-3, development of a tool to train engineers for efficient and rapid damage assessment using virtual reality (VR), seismic performance and vulnerability of existing masonry buildings built in aggregates, preliminary and rapid analysis of the seismic resistance of existing structures using visual programming, damage assessment using unmanned aerial vehicles (UAV), development of an improved digital form for visual damage assessment taking into account experience from past earthquakes, development of form for damage assessment of bridges, and seismic risk assessment of educational buildings in Croatia.

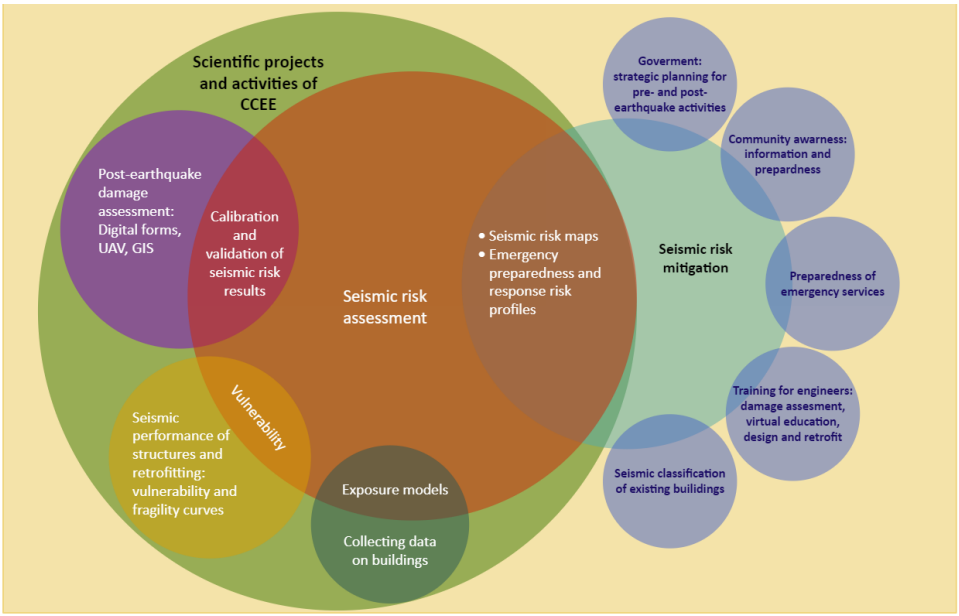

Figure 2. Flowchart of CCEE projects and activities for the development of a resilient community in Croatia

A brief description of Research Achievements and Challenges:

The main challenges of the CCEE team are:

- Development and implementation of methodology for seismic certification.
- Improvement of existing damage assessment methodology and digital forms for visual inspection.
- Improvement of retrofit techniques and methods.
- Improvement of existing and application of new methods for seismic risk assessment and development of reliable exposure, fragility, and consequence models.
- Advancement of experimental and numerical simulation techniques through various scientific projects.
- Disseminating earthquake engineering knowledge to increase awareness of seismic risk in the community and raising of the level of knowledge in general.
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The research achievement of the CCEE team can be summarized as follows:

Scientific project leading:

- (2021 – 1st Jan 2024) Members of CCEE are a part of the team of the project "Seismic Risk Assessment of the City of Zagreb", funded by the European structural and investment funds. The project's primary goal is to develop a detailed exposure model of buildings, collect data building by building, conduct a seismic risk analysis using OpenQuake developed by the Global Earthquake Model Foundation and present the results to the city authorities and emergency services. Since a quarter of the Croatian population lives in the City of Zagreb, the project is intended to be a pilot project for seismic risk assessment for the whole Croatian territory.
- (2022 – on-going) Research grant holders for the research project entitled "New vulnerability models of typical buildings in urban areas: applications in seismic risk assessment and target retrofitting methodology – 2BESAFE ", the aim of which is to improve methods for a comprehensive definition of the behavior of structures under seismic action, and to develop a methodology for targeted retrofitting of critical structures.
- (2020 – on-going) Research grant holders for the research project entitled "Assessment and Reconstruction of Existing Structures – ARES" focused on lowering the earthquake risk for masonry and wooden structures.
- (2021 – 2022) Partner of the project "Learn to be Resilient – L2BR" funded by ECHO (DG for European Civil Protection and Humanitarian Aid Operations) under the coordination of Réseau des Associations Nationales de Pouvoirs Locaux de L'Europe du Sud-Est (NALAS).
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Participation in projects and technical committees:

- Members of the working group for creating the National strategy until 2030
- Members of the working group for security for developing the National Development Strategy until 2030 and the technical committee HZN / TO 548 / PO 8 (Eurocode 8).
- Part of the national MUSAR rescue team from the ruins (within the Civil Protection Directorate of the Ministry of Interior of the Republic of Croatia) as a construction expert with experience in numerous exercises (Alessandria 2015, Ston and Austria 2016, Istria 2017 and Cascade19 in Portugal)
- Collaboration on the project "Management Plan for the Protected Monument of the City of Dubrovnik" led by the Faculty of Architecture, University of Zagreb (UNESCO initiative).

- Participation in the implementation of the Interreg project "Resilience Enhancement of the Adriatic Basin from companies and SeiSmic hazards – READINESS" within which buildings of special (strategic) importance, such as schools and hospitals. Capability).
- Active contribution to developing the European earthquake exposure model within the Horizon 2020 SERA project.
- Participation in the international project "Matilda" (MultinATIonal module on Damage Assessment and CounTermeasures – Civil Protection Preparatory Action on an EU Rapid Response Capability).
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Higher education:

- Lecturers in **undergraduate study courses**:
  - Mechanics 1, Mechanics 2, Structural analysis 1, Concrete structures 1, Masonry structures, Strength of Materials 1 and 2, Concrete and Masonry Structures, Numerical Modelling of Structures, Metal Structures, Bridges, Railways, Construction Management, Education on Construction Site.
- Lecturers in courses of the following **graduate programs**:
  - Structural Engineering, Theory and Modelling of Structures, Construction Materials, Construction Management, Hydraulic Engineering and Transportation Engineering.
- In 2022, a new **post-graduate specialist study entitled "Earthquake Engineering"** was approved by the Ministry of Science and Education. The study is being held for the first time in this academic year, 2023/2024, with 15 students enrolled. A brief description of the program: The post-graduate specialist study Earthquake Engineering is intended as a form of professional development, i.e., lifelong learning, primarily for civil and advanced architectural engineers who deal with the design and construction of seismically resistant buildings. The study is based on the application of scientifically based knowledge about the behavior of structures in an earthquake and modern standards for seismic-resistant design. Participants will be able to acquire knowledge and skills in the field of structural dynamics, application of modern methods of analyses, techniques for strengthening existing structures, rehabilitation of historical buildings – cultural heritage, methodology for earthquake risk assessment, testing of structures and materials, seismic-resistant design of bridges, application of isolators and other devices for energy consumption, the use of modern materials and construction technology.
- …

Post-earthquake activities:

- Participation in damage assessments of buildings after the earthquake in Albania (2019) as part of the assistance of the Government of the Republic of Croatia activated through the Coordination Center for Emergency Response (ERCC) of the Civil Protection Union Mechanism.
- The main coordinators of the damage and usability assessment of buildings after the earthquake in Zagreb in March 2020 and after the earthquake in Petrinja in December 2020, by organizing a system for damage assessments of buildings and forming crisis headquarters for the management of engineers and civil services involved in relief activities.
- Development and integration of a digital form for damage assessment and usability classification of buildings into a Geospatial Information System (GIS) application.
- Organization of on-site education and training to help engineers conduct reliable damage assessments after earthquakes.
- Development and management of GIS databases containing information on 25,000 buildings after the Zagreb earthquake and more than 46,000 buildings after the Petrinja earthquake, which were directly accessible to all interested parties (emergency services, various city offices, government services and offices – decision makers).
- Organization of an expert working group to prepare a reconstruction plan, which resulted with the basis for the development of technical laws and regulations.
- Organization of various expert meetings and consultations to help all participants included in post-earthquake reconstruction efforts, organization of webinars and online consultations.
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Figure 3. Headquarters for operational field management at the EMO and volunteers-experts in the field during the COVID-19 pandemic

Studies and technical reports:

- Authors of the Seismic Risk Assessment for the City of Zagreb, 2024.
- Authors of the Seismic Risk Assessment of Croatia in 2014 and of the updates in 2018 and 2022 in collaboration with Ministry of Physical Planning, Construction, and State Assets.
- Development of a disaster risk management strategy, 2018 – 2020.
- Authors of a series of 8 studies for mitigation of the consequences of earthquakes in the City of Zagreb, 2014 – 2022.
- Technical support and consultants for preparation of the document "CROATIA EARTHQUAKE 2020: Rapid Damage and Needs Assessment" after the Zagreb earthquake and "CROATIA DECEMBER EARTHQUAKE 2020: Rapid Damage and Needs Assessment" after the Petrinja earthquake in collaboration with the World Bank and Croatian Government.
- Technical support and consultants for preparation of the document "Rapid Damage and Needs Assessment for the Cities of Sisak, Petrinja, and Glina – December 2020 Earthquake" after the Petrinja earthquake in collaboration with the World Bank and Croatian Government.
- Authors of the document "Report on Seismic Risk Assessment of Emergency Response Facilities in Croatia – Supporting disaster resilience in Croatia", the World Bank, 2023.
- …

Active professional projects of seismic performance and retrofitting of damaged buildings:

- Zagreb Cathedral (2021 –)
- National Theater Building (2022 –)
- Palace of Justice (2022 –)
- Seismic performance assessment of the building of the University of Zagreb (2021 -)
- Building of the Faculty of Teacher Education, Petrinja (2021 -)
- …

Authorship of books and manuals:

- Authors of the manual "Urgent Program of Seismic Reconstruction" in collaboration with the Croatian Chamber of Civil Engineers (2020).
- Authors of the book "Retrofitting of Masonry Buildings" (2021).
- …

Organization of conferences, symposium, and workshops:

- Organization of 1st Croatian Conference on Earthquake Engineering 1CroCEE 22 – 24 March 2021, Zagreb, Croatia
- Organization of 2nd Croatian Conference on Earthquake Engineering 2CroCEE 22 - 24 March 2023, Zagreb, Croatia
- Workshop on seismic hazard and risk assessment using OpenQuake, Zagreb, September 2023.
- …

Organization of lecturers and training for experts and engineers:

- Series of scientific and professional lectures to help recover the community after the 2020 Zagreb and Petrinja earthquakes, 2020 – 2021. Recordings of the videos can be found on the following link: www.hcpi.hr/webinarisavjetovanjapredavanja-67
- Vitor Silva, "Earthquake Risk Assessment: Are We Doing Enough?, January 2021.
- The Building Centre of Japan, "Build Back Better Together – Supporting the Post-Earthquake Reconstruction through Japan-Croatia Knowledge Exchange", September 2022.
- Paulo Bazzuro, Development of fragility curves for risk assessment of specific buildings focusing on ground motion selection techniques: dos and don'ts, Zagreb, January 2023.
- …

Comparative advantage/contribution to GADRI Activities:

- The CCEE was established to pool the knowledge and experience of Croatian researchers in the field of earthquake engineering and **to help** Croatian citizens and the entire community after disasters such as earthquakes or other events. Dissemination of scientific knowledge to engineers, design and construction companies and decision makers has been recognized as a priority in developing a resilient system. A strong network with the government and municipalities after the recent earthquakes has become an excellent basis for the application of scientific research results from GADRI members to validate, calibrate, modify, and directly implement the results in the Croatian system.
- The importance of solid alliance organizations such as GADRI can be highlighted by good knowledge dissemination and implementation in the Croatian disaster risk reduction system. The lessons learned from past

earthquakes could be an excellent example for other countries with similar structural typologies and communities in East-Central Europe and the Balkan regions, but also for other small countries worldwide where the seismic risk is high.

Expected Outputs/Results:

- Croatia, as a small country, has proven its adaptable capacity after the recent earthquakes in 2020, but the disaster risk reduction system is still in the development phase. The main objective of CCEE is to support authorities and decision-makers in disaster preparedness and reducing the seismic vulnerability of buildings and infrastructure, improving the response capacity to disaster events, and making the whole community more resilient. To achieve these goals, the most important steps and activities should be defined and prioritized in this early development phase. The extensive knowledge and experience of experts such as those at GADRI could be crucial in establishing these key steps.
- Preventing disasters and responding effectively to catastrophic events through high-quality scientific research programs by learning from the experiences of GADRI members.