POLITECNICO DI MILANO

PhD in INGEGNERIA STRUTTURALE, SISMICA, GEOTECNICA / STRUCTURAL SEISMIC AND GEOTECHNICAL ENGINEERING - 40th cycle

THEMATIC Research Field: LINED/REINFORCED CAVERNS FOR HYDROGEN STORAGE: MATERIALS AND TECHNOLOGIES FOR STRUCTURAL STABILITY

Monthly net income of PhDscholarship (max 36 months)
€ 1500.0 In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	As infrastructures for energy production and storage evolve to meet carbon neutrality goals, hydrogen stands out as a critical clean energy carrier, offering a pathway for high-capacity and long-term energy storage. Among various storage technologies, the development of Lined Rock Caverns (LRCs) for underground hydrogen storage is particularly promising. LRC technology provides a modular and scalable solution for energy storage that complements larger-scale options, such as salt caverns and gas reservoirs, and can potentially be implemented across diverse geological conditions. This research aims to advance LRC technology for hydrogen storage by optimizing the design and material composition of cavern linings. While LRC technology has been successfully used for natural gas, adapting it for hydrogen introduces unique challenges related to gas pressure, permeability requirements, and the impacts of hydrogen on structural integrity. By addressing these challenges, the project seeks to develop a robust, versatile, and safe approach to hydrogen storage, aligned with future energy infrastructure needs.
Methods and techniques that will be developed and used to carry out the research	To achieve the project's objectives, several methodologies will be developed and employed:

	•Geomechanical and Structural Analysis: investigate the interaction between the LRC structures and surrounding rock mass, accounting for the shape, geometry, pre-existing stress states, and alignment of the cavern within various geological conditions. Assess factors such as water pressure and temperature variations to optimize the cavern's design and operational performance. •Material Stress and Fatigue Testing: conduct stress and deformation analyses on the concrete lining, particularly focusing on the impacts of cyclic filling and emptying processes that induce fatigue. Evaluate potential crack formation and propagation within the concrete, ensuring stable load transfer to the surrounding rock mass. •Metal Lining Durability and Hydrogen Compatibility: examine the metal lining's response to hydrogen exposure, including the effects of fatigue, corrosion, and hydrogen embrittlement. Develop or adapt corrosion-resistant materials to prolong lining lifespan and maintain gas impermeability. •Field Validation and Pilot Testing: in the final project phase, apply the developed technology at a test site. This will involve a thorough analysis of surface infrastructure requirements, linking underground storage to potential distribution networks and operational strategies for hydrogen management.
Educational objectives	This PhD project offers a comprehensive educational experience, fostering interdisciplinary expertise across fields such as geotechnical engineering, materials science, and energy systems design. The candidate will gain: •Advanced technical knowledge: a solid foundation in hydrogen storage technology and an understanding of LRC applications within broader carbon-neutral energy infrastructures. •Practical research skills: Hands-on experience in

	geomechanical modeling, material concept and structural design with advanced cement based materials, material durability testing, and system analysis. •Project management and collaboration: the opportunity to engage with industry partners, gaining skills in project planning, teamwork, and effective communication across academic and industrial settings.
Job opportunities	Graduates of this PhD program will be well-prepared for careers in both academia and industry. Key opportunities include roles in energy infrastructure development; research and development in clean energy technologies; geotechnical and structural engineering, including roles in consulting firms focusing on underground storage and advanced materials.
Composition of the research group	1 Full Professors 2 Associated Professors 8 Assistant Professors 15 PhD Students
Name of the research directors	Ferrara Muciaccia Della Vecchia

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Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents (more than 80Km out of Milano)	--

Scholarship Increase for a period abroad	
Amount monthly	750.0 €
By number of months	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information
Educational activities (purchase of study books and material, funding for participation to courses, summer schools, workshops and conferences): financial aid per PhD student per year The Ph.D.

course supports the educational activities of its Ph.D. students with additional funding equal to 10% of the scholarship, starting from the first year.

Teaching assistantship: availability of funding in recognition of support to teaching activities by the PhD student There are various forms of financial aid for activities of support to the teaching practice. The PhD is encouraged to take part in these activities, within the limits allowed by the regulations.

Computer availability: Each Ph.D. student has his/her own computer for individual use.

Desk availability: Each Ph.D. student has his/her own desk, cabinet and locker.