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### ► To cite this version:

Ton Peters, Suzanne van Eekelen, Ioannis Anastasopoulos, Evangelista Korre, Sam Stanier, et al.. GEOLAB: integrating and advancing Europe's physical modelling facilities. ICPMG 2022, 10th International Conference on Physical Modelling in Geotechnics, Sep 2022, Daejeon, France. pp.140-144. hal-04119813

**HAL Id: hal-04119813**

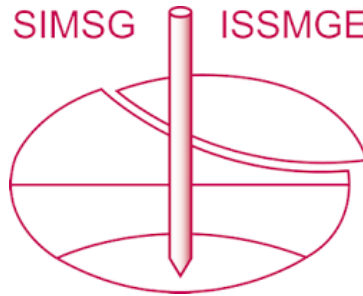
**<https://hal.science/hal-04119813v1>**

Submitted on 11 Sep 2023

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*The paper was published in the proceedings of the 10th International Conference on Physical Modelling in Geotechnics and was edited by Moonkyung Chung, Sung-Ryul Kim, Nam-Ryong Kim, Tae-Hyuk Kwon, Heon-Joon Park, Seong-Bae Jo and Jae-Hyun Kim. The conference was held in Daejeon, South Korea from September 19<sup>th</sup> to September 23<sup>rd</sup> 2022.*

## GEOLAB: Integrating and advancing Europe's physical modelling facilities

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**ABSTRACT:** The critical infrastructure of Europe is currently facing multifaceted challenges. The GEOLAB research infrastructure comprises 12 unique facilities in Europe for studying ground behavior and its interaction with structural elements and the environment. The aim of GEOLAB is to integrate and advance these national facilities into a one-stop-shop for performing excellent physical modelling research and innovation for enhancing the resilience of critical infrastructure. The joint research activities are advancing the capabilities of the GEOLAB facilities beyond present state-of-the-art. During transnational access, experiments proposed by outside user groups are carried out.

**Keywords:** research infrastructure, data, physical modelling, numerical modelling, critical infrastructure.

### 1 INTRODUCTION

The GEOLAB Research Infrastructure (RI) comprises 12 unique facilities in Europe for studying ground behavior and its interaction with structural elements and the environment. It includes 6 Geo-Centrifuges of different sizes and capabilities, a Geo-Model Container, a Static Liquefaction Tank, a Pile

Foundation Test Pit, a Large-scale Triaxial Apparatus, a Railway Track Simulator and a set of six Field Test Sites. (Estaire et al., 2021)

These facilities represent excellent geotechnical experiment facilities available in Europe today. However, until recently, work in these facilities has been independent and uncoordinated. The 4 year GEOLAB

project, led by Deltares, started in February 2021, with the aim to integrate and advance these national facilities into a one-stop-shop for performing excellent physical modelling research and innovation.

The GEOLAB project has three core components. In its Transnational Access (TA), stakeholders gain access to the GEOLAB RI when they respond to calls for proposals that aim to enhance the resilience of Critical Infrastructure (CI). In the second component, the GEOLAB partners collaborate in Joint Research Activities (JRA) with the goal to advance the capabilities of the RI beyond present state-of-the-art. This will not only enable ground-breaking experiments, but also improve on re-use of experiment data sets. Networking Activities (NA), including knowledge sharing and training of next generation users, form the third core element of GEOLAB. In these activities the interaction between physical models, numerical models and big data, as well as between physical models and the environment, are highlighted.

## 2 GEOLAB RESEARCH INFRASTRUCTURE

### 2.1 Why GEOLAB?

The existing CI of Europe in the water, energy, urban and transport sector (Fig. 1), is currently facing multifaceted challenges. Climate change, and with that the increase in extreme weather and geo-hazards events, are placing additional pressures on these infrastructures. Many of the CI are still in use long past their expected design life. In addition, society requires pivotal changes in the way we run these CI systems to meet long-term goals, e.g. reduction of greenhouse gas emissions, energy transition, less environmental impact and lower operational costs. Strengthening CI resilience to meet present and future challenges and demands should therefore be at the forefront of societal goals, and to this end, excellent research and innovative solutions are needed.

A crucial aspect to building the resilience of CI networks is ascertaining the integrity or stability of the structure itself, particularly as experience has shown how failure of the structure can usually result in major operation loss, with consequent economic loss and, sometimes, loss of lives. This structural integrity depends to a great extent on the properties and behavior of the ground materials on which the structure is built, and on the interaction of these materials with the structure, as well as with the environment (e.g. rainfall triggering landslide). A comprehensive and in-depth understanding of this behavior and interaction is critical for enhancing CI resilience. This is best achieved through interdisciplinary, cross-boundary research and by equipping expert teams with the most advanced suite of physical RI available. GEOLAB aims to develop and improve this set of RI in order to address the challenges

faced by the CI of Europe.

Critical Infrastructure (CI):	
Energy	Oil, gas production and related pipelines
	Electricity generation and transmission
	Distribution electricity, oil, gas
Water	Drinking-water and sewage system
	Surface water, flood protection
Urban	Public buildings, offices
	Monuments, historic buildings
	Resident housing
	Underground construction
Transport	Road & rail infrastructure
	Airports
	Ports and inland waterways
	Pipelines

Fig. 1. Overview CI networks.

### 2.2 Research facilities

GEOLAB provides a suite of 12 complementary facilities equipping the users from academia, CI managers and industry with renowned tools for excellent research.

The facilities were specifically selected to ensure a wide range of capabilities to address problems across experiment scales, disciplinary boundaries and Technology Readiness Levels (TRL), see Fig. 2.

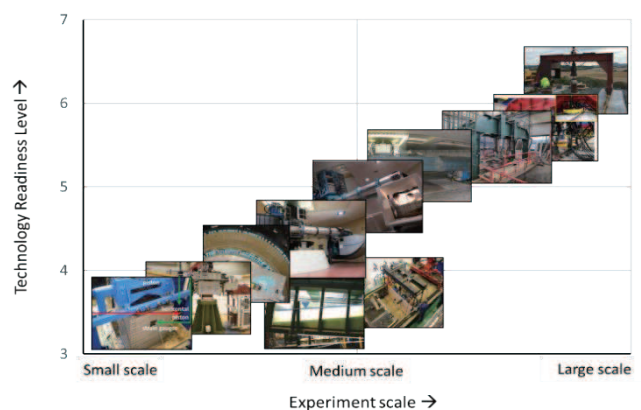


Fig. 2. Complementarity of the GEOLAB research facilities.

In order to prove concepts or hypotheses and test small & medium scale prototype solutions (up to TRL 4) three facilities are available: The soil-water liquefaction tank of the Delft University of Technology, the GeoModel container of Deltares and the Large-scale Triaxial Apparatus of the University of Maribor/ZAG. GEOLAB has two facilities to test large scale prototype solutions in the intended environment (up to TRL6): the CEDEX Railway Track Box and the Pile Foundation

Test Pit of TU Darmstadt.

GEOLAB provides a coherent set of six centrifuges, with different sizes, capabilities and features for research. They are owned by Deltares, Delft University of Technology, ETH Zürich, University Gustave Eiffel and Cambridge University.

Finally, to prove innovative solutions in the operational environment at pre-commercial scale (up to TRL 7), we have access to the Norwegian GeoTest Sites facility.

### 3 JOINT RESEARCH ACTIVITIES

The main goal of the JRA is to advance the capabilities of the RI beyond present state-of-the-art, by:

- Integrating and synergizing the experimental RI.
- Improving the physical modelling and measurements techniques.
- Standardizing data management and establishing an open access database for efficient data exchange between facilities and re-use of experiment data sets by other research institutions.

#### 3.1 Experimental challenges / technology readiness

Systematic assessment of experimental challenges is key to successful improvement of the capabilities of GEOLAB. A critical review of the short-term experimental challenges was conducted to define needs in terms of instrumentation, experimental capabilities, and experimental techniques.

Technology readiness is defined as the maturity of a new technology or methodology. An important step in reaching the objectives of the JRA was to assess the potential of new technologies for the experimental investigations of GEOLAB (Marin et al., 2021).

#### 3.2 Standardization and re-use of experiment data

A major step forward in the integration of the research facilities and advancing interoperability comes from the development of joint standards for data. The GEOLAB Data Management Plan (Žlender et al., 2021) defines the life cycle of data collected, processed and stored. A key success factor is virtual access to research data and the ability to share and re-use research data beyond the group that captured the data. This requires that participants make their publications and research data Findable, Accessible, Interoperable and Reusable (FAIR).

We aim for a virtual open access database of well-documented experimental results. Several platforms have been assessed to enable such an open access database. Two platforms, Zenodo and DesignSafe have been compared in depth, as shown in Fig. 3. The DesignSafe platform (Rathje et al., 2017) was selected as a first choice. Additional benefit of DesignSafe is its international outreach in the civil engineering community.

Characteristics	DesignSafe	Zenodo
Region of platform	USA	EU
Registration of users (curators)	with conformation of Admin	without conformation
Multiple curators	allow	do not allow
Data curation:	structure tailored to experimental facilities	structure of project data is not generated.
Data depot structure	My data, My project.	not possible
Cloud storage space	Box, Dropbox and Google Drive	not connected
User guide:	user guide and video tutorials	no user guides.
Additional software	analyses and simulation software	not provided
Time limitation of the platform	intend to keep all data available.	20 years
DOI:	automatically generated	automatically generated.
Project/Experiment	more experiments in a project.	only project can be generated
Costs:	free of charge	Free of charge
Citation:	automatically generated	Automatically generated
Limitation of data space storage	50 GB, higher quota on request	50 GB, higher quota on request

Fig. 3. Comparing the DesignSafe and Zenodo platforms

### 4 TRANSNATIONAL ACCESS

During TA, GEOLAB performs experiments proposed by users outside the consortium from academia, industry and CI managers. The access is funded from the project budget and includes technical & scientific support and training.

#### 4.1 The aim of TA user projects

In the knowledge development, the main actors are users from academia and CI managers where they make observations, apply theories and formulate hypotheses which are tested in the GEOLAB facilities. The experiments will answer research questions, such as:

- What is the impact of climate change and increase of extreme weather events and geo-hazards on CI?
- How does the aging of ground and structure affect the performance CI?
- What is the complex integral behavior of a system of several CI networks?

The knowledge development is followed by technology development on solutions to enhance the resilience of CI. Users from industry and academia will

Selected user project	Leader of the user group	Facility providing access	Score
PEBSTER: Piled Embankment with basal steel reinforcement	Keller, Poland (contractor)	Deltares GeoHall & TUDa Pile Foundation Test Pit	97%
CLARIFIER: Centrifuge modelling of peat embankments	University College Dublin, Ireland	Deltares Geo-Centrifuge	95%
SAFETY: Stability analysis for enhanced mine tailings storage facilities	University of Porto, Portugal	Deltares Geo-Centrifuge	86%
CENTRIPLUG: open-ended pile-soil interaction with respect to soil plugging in cohesive soils	Helmut-Schmidt-University, Germany	TU Delft Geotechnical Centrifuge	82%
JELLYFISH: Innovative in-situ soil testing technology (Medusa DMT/SDMT)	University of L'Aquila, Italy	NGI Geotest Sites	87%
QC-CEM/RELERT: Quick Clay Common Earth Modelling and ERT geophysical investigation	Luleå University of Technology, Sweden & Technical University of Munich, Germany	NGI Geotest Sites	77%
WESDOM: Wind – Earthquake – Storm design Offshore Wind Turbines foundations	GR8 GEO, Greece (consulting firm, SME)	ETHZ Beam Centrifuge	91%
CENLIMIT: Centrifuge modelling of desaturation for soil liquefaction mitigation	University of Porto, Portugal	UCAM Centrifuge	81%
CTP-ISSR: Centrifuge tests on piles in sand to enhance structural resilience	University of Napoli, Italy	UCAM Centrifuge	77%
SHARP: Soil heterogeneity for soil amelioration in road projects	CNR-IRPI, Italy (research institute)	UM/ZAG Large-scale Triaxial Apparatus	95%
LIWEMAT: Deformation characterization of lightweight foundation materials	Cyril and Methodius University in Skopje, North Macedonia	UM/ZAG Large-scale Triaxial Apparatus	78%
HSRTSUB: Resilience of stabilized and conventional high-speed rail track subgrades	Afyon Kocatepe University, Turkey	UM/ZAG Large-scale Triaxial Apparatus	77%
TAPILES: Testing of innovative foundation piles with diameter decreasing with depth.	Gdańsk University of Technology, Poland	Uni Eiffel Geotechnical Centrifuge	73%
PEDLER: Performance and durability of Light Weight Aggregates in railway embankments	Leca International, Denmark (supplier)	CEDEX Track Box	84%

Fig. 4. Selected user projects granted access to the GEOLAB facilities, after responding to the first call for proposals.

collaborate and use the access to the GEOLAB facilities to test prototype solutions in the lab and demonstrate their efficacy at pre-commercial scale. The technology development will focus on:

- Application of new construction materials, for example: self-healing materials, bio-based materials, recycled materials and smart materials.
- Implementation of new methodologies, for example: nature-based solutions and prefabricated parts.
- New future proof CI design approaches.

#### 4.2 Transnational Access policy

The facility providers have adopted a common user selection procedure for choosing the users groups that will be granted access to the research facilities. The selection procedure and access to the facilities are governed by the Policy on Transnational Access (Korre et al., 2021). It involves a fair competition when user groups respond to calls for proposals. As part of the selection process, a User Selection Panel evaluates all proposals based on clear criteria. This panel consists of

10 to 12 independent experts in the fields covered by the facilities of GEOLAB.

The first (out of 3) round of Transnational Access was finalized in December 2021 in which 14 proposal were selected. The user projects, as presented in Fig. 4, are foreseen to run in 2022. The next call-for-proposals is expected in the spring of 2022.

## 5 CONCLUSIONS

The GEOLAB project has been established to integrate and advance national facilities on ground behavior and interaction with structures and the environment. The overarching aim is to enhance the resilience of the critical infrastructure in Europe.

Systematic assessment of short-term experimental challenges and the potential of innovative technologies were conducted. For re-use and sharing of experiment data the DesignSafe platform was selected as a first choice. During the first round of transnational access 14 proposal were selected that are foreseen to run in 2022.

## ACKNOWLEDGEMENTS



This project has received funding from the European Union's Horizon 2020 research and innovation program under Grant Agreement No. 101006512.

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