Technical background Critical Infrastructure and GEOLAB research & innovation

Critical Infrastructure challenges

The existing Critical Infrastructure (CI) of Europe in the water, energy, urban and transport sector is currently facing multifaceted challenges. Climate change, and with that the concomitant increase in extreme weather and geo-hazards events, are placing **additional pressures** on these fragile infrastructures, that are often already weakened by aging. Many of these infrastructures are still in use long past their expected life span, with little expectation of replacement. At the same time, their use is steadily increasing while budgets for repair and maintenance are not growing at the same pace, compromising their reliability. 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, increase in the share of renewable energies, transition to "smart mobility'', less congestion, higher safety, less environmental impact and lower operational costs.

	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

Figure 1. Overview different types of CI networks

In an increasingly interconnected, globalised world, society heavily relies on CI for safety, quality life and economic success. This has never been demonstrated so severely as during the current COVID pandemic, where the continuity of societal life is greatly depending on the availability and reliability of select critical functions and infrastructure sectors, e.g. health and medical, telecommunication and internet, energy, water and others. Strengthening and enhancing 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 (Figure 1) is ascertaining the integrity or stability of the structure itself, particularly as past experience have 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 behaviour of the subsurface materials on, in or out of which (i.e., as building material) the structure is built, and on the interaction of these materials with the structure or components thereof, as well as with the environment (e.g. rainfall triggering landslide). As such, a comprehensive and in-depth understanding of this behaviour and interaction is critical to enhancing CI resilience. Furthermore, a clear knowledge of how this behaviour and interaction are influenced by expected changes in environmental (e.g., climate change) and loading conditions (e.g., increased traffic) is of utmost importance if we are to effectively and efficiently adapt the design, construction, operation and maintenance of the CI to these changes. Such knowledge and understanding are best achieved through interdisciplinary, cross-boundary research and by equipping expert teams with the most advanced suite of physical research infrastructure available that will allow them to perform scientific work across spatial scales, explore different theories and approaches, and adopt innovative techniques.

GEOLAB research and innovation

GEOLAB provides a comprehensive suite of 11 complementary installations equipping the users from academia and industry with renowned tools for excellent research for the energy, water, urban and transport infrastructure sector. The installations were specifically selected to ensure a wide range of capabilities to address problems across experiment scales, disciplinary boundaries and Technology Readiness Levels (TRL). The research infrastructure installations are used to study the following:

- Ground stability related issues, e.g. consolidation, seepage, liquefaction, (coastal) erosion and slope stability.
- Water-soil-structure interaction, e.g. for roads, railways, tunnels, bridges, dams, foundations, buildings and buried cables & pipelines.
- Interaction of infrastructure systems with the environment, e.g. impact of climate change, extreme weather events, geo-hazards, static & dynamic loading and aging.

The laboratory installations are complemented by a set of in-situ test sites. In Figure 2 an overview of the installations is shown.

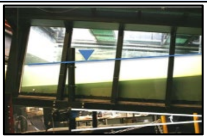
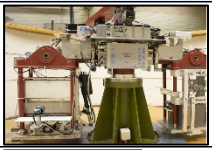
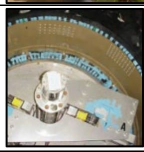
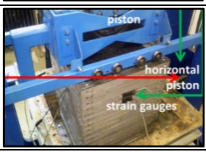
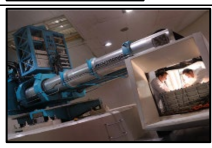
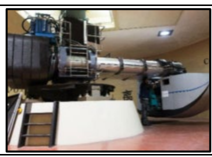
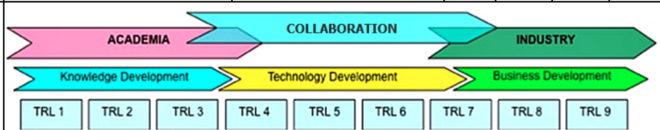
Research Infrastructure	Features	Application				Research Infrastructure	Features	Application			
		Energy	Water	Urban	Transport			Energy	Water	Urban	Transport
	Static Liquefaction tank 5 x 2 x 2 m TRL 3 – TRL4	X	X		X		Geo-centrifuge Beam 1.3 m TRL 3 – TRL4	X	X	X	X
	GeoModel container 4 x 2.5 x 1.2 m TRL 3 – TRL4	X	X	X	X		Drum centrifuge Diameter 2.2 m TRL 3 – TRL5	X	X	X	X
	Large-scale TriaxialApparatus 0.7 x 0.7 x 1.2 m TRL 3 – TRL4			X	X		GeoCentrifuge Beam 5.5 m TRL4 – TRL6	X	X	X	X
	CEDEX Track Box 21 x 5 x 4 m TRL5 – TRL6			X	X		Geotechnical centrifuge Beam 5.5 m TRL4 – TRL6	X	X	X	X
	Pile Foundation Test Pit 19.4 x 5 x 3/6 m TRL5 – TRL6	X		X	X		Cambridge centrifuge Beam 10 m TRL4 – TRL6	X	X	X	X
	GeoTest Sites 5 field sites TR6 – TRL7	X	X	X	X	 *Source: uk-cpi.com*					

Figure 2. Overview GEOLAB's installations

The 11 installations are suitable to provide services for both knowledge and technology development, in the TRL range TRL3 to 7, see bottom right of Figure 2. In the knowledge development (TRL1-3), the main actors are users from academia where they make observations, apply theories and formulate hypotheses which are tested in the GEOLAB installations (TRL3 experimental proof of concept). From the access to the installations, ground-breaking experiments will answer, among others, the following research questions:

- What is the impact of climate change (and concomitant risk increase of extreme weather events and geo-hazards), on the CI?
- How does the aging mechanism of soil and structure under various loading conditions (vibration, temperature, moisture, rainfall cycles, etc.) work and how does it affect the performance CI?
- What is the influence of very high-speed mobility (Hyperloop systems) on the wave propagation and soil deformation?
- What is the complex integral behaviour of a system of CI (for example multi modal transport hubs)?

The knowledge development is followed by technology development on solutions (TRL4-7) to enhance the resilience of CI. Users from industry and academia will collaborate and use the access to the GEOLAB installations to test prototype solutions in the lab (TRL4-5), in the intended environment (TRL6) and demonstrate at pre-commercial scale in the operational environment (TRL7). The technology development will focus, among others, on the following research topics to enhance the CI:

- Application of new construction materials, for example: self-healing materials, bio-based materials, re-used/recycled materials, materials with cooling/heating effects and smart materials (including sensing).
- Implementation of new methodologies, for example: prefabricated retrofitting and nature-based solutions.
- New future proof CI design approaches using data and numerical modelling for increased flexibility, adaptability and scalability.
- Optimal solutions to adapt existing CI to new usage patterns, for example the impact of construction of new CI on the adjacent, existing CI.