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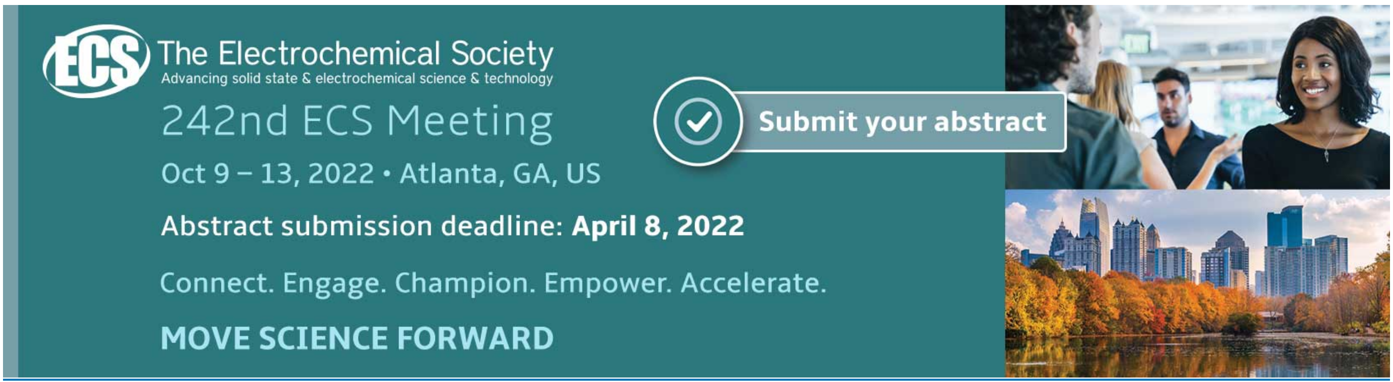
To cite this article: P Paniagua *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **710** 012069



Transport infrastructure and geotechnical engineering: ELGIP position paper

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Abstract. The European Large Geotechnical Institutes Platform (ELGIP) is a group of 14 European research organizations, leading in geotechnical engineering, which aims to promote internationally the profession, its network and its societal relevance. One ELGIP vision is that all transport infrastructure should aim for an optimal geotechnical design. The present paper shows the relationship between the pressing challenges on European transport infrastructures and the crucial role that geotechnical engineering plays in solving them, emphasising the need for improved knowledge and understanding of ground properties in transport infrastructure.

1. Introduction

Reducing the vulnerability of our transport infrastructure to climate change and the disastrous consequences of natural hazards is a societal responsibility and an achievable policy imperative. Uncertainties and lack of knowledge when dealing with subsurface variability leads to unnecessarily expensive and less sustainable infrastructure design. A considerable value to society can be achieved if geotechnical issues are included in practical strategies. This will improve the overall resilience of transport infrastructure.

Modern society faces a continuous challenge to provide a safe and efficient transportation network for people and goods. New transport infrastructures must be designed in a more resilient, sustainable and affordable manner. Simultaneously, existing structures need to be maintained, retrofitted and repurposed. The European Large Geotechnical Institutes Platform (ELGIP) urges policy makers, transport engineers, risk managers, geoscientist and engineers, to collaborate at early stages when planning, building and maintaining transport infrastructure.

The purpose of this position paper is to:

- Show the relationship between the pressing challenges on European transport infrastructures and the crucial role that geotechnical engineering plays in solving them,
- Promote the invitation of geotechnical engineers to participate active in implementing public policies dealing with Europe's transport infrastructure, and
- Define the strategic research direction for leading-edge technologies in the built and natural environment.

2. Transport infrastructure in numbers

Transport is a key factor in modern economies. Mobility is essential for the European quality of life, vital for the European Union’s competitiveness and is a significant employer. The European transport industry directly employs more than 10 million people, accounting for 4.5% of total employment, and represents 4.6% of GDP.

Building and maintaining infrastructure is a critical and sometimes even lifesaving undertaking. McKinsey [1,2] estimates that the world needs investments of about $57 trillion on infrastructure by 2030 to enable the anticipated levels of GDP growth globally. It can take up to 20 years to build a motorway, from planning to construction. The average cost per km varies depending on the location and complexity of the route. It can be as low as €7.1 million and as high as €90 million or even more!

However, nine out of ten infrastructure projects have cost overruns averaging 28% [3]. Studies by Lind & Burns [4] show that most cost overruns occur in the initiation and planning stages up to the final design and are related to design changes and increases in the amount of data needed because of unforeseen technical problems and uncertainties in ground conditions and design parameters.

3. Transportation infrastructure depends on geotechnical engineering

All infrastructures and transportation hubs are either built on or within the subsurface consisting of soils and rock (Figure 1). Geotechnical engineering is therefore the foundation of all transportation infrastructure projects. Between 80% and 85% of all building failures and damages in Europe relate to unforeseen ground conditions. A minimum figure for a typical site investigation is around 0.5% of the total construction costs of a given project [5]. However, unforeseen ground conditions attributable to inadequate investigation can frequently increase costs of projects by 10% or more.

Geotechnical engineering largely involves defining the soil's strength and deformation properties. It includes specialist fields such as soil and rock mechanics, geophysics, hydrogeology and associated disciplines such as geology. Geotechnics is applied when planning infrastructure such as roads and tunnels as well as buildings and other constructions. Unlike steel and concrete, the material properties and behavior of soil are difficult to predict due to its variability. Knowledge of ground conditions depends on the extent and quality of the geotechnical investigations and these always follow a given budget. Furthermore, soil exhibits complex behavior, making the choice of reliable geotechnical design parameters all the more challenging and crucial for the final result.

Figure 1. Subsurface conditions must be revealed to plan, design and construct cost-effective infrastructure. The soil conditions may vary drastically over short distances. Modern techniques can be utilized to effectively see spatial variability in subsurface conditions.

For example, on December 6th, 2006, during the construction of a new part of road E6 in a quick clay area at Munkedal in Sweden, a landslide occurred affecting the old road. Several cars were drawn into the landslide. About 500 m of road and 20 0m of the adjacent railway were destroyed. Fortunately, no one died. The costs for reconstruction alone were about €52 million. The landslide occurred due to incorrectly stored masses of subbase materials that triggered the slide [6].

Another example, on March 20th, 2012 a retaining structure along motorway A13 in Austria between Innsbruck and Brenner to Schönberg suddenly collapsed [7]. This 40-year-old concrete structure was designed according to the standards that had to be met at that time. It was regularly inspected but failed only weeks after the last inspection. The retaining wall failed extremely rapid due to a combination of unexpected loading (by water accumulation behind the wall due to exceptionally high snow melt), structural problems and brittle behavior. As a result, a truck driver was killed. Also, potential risk led to the control of other similar retaining walls, and after the evaluation some parts were reconstructed.

To put this in perspective, in the years 2000-2006 the European Union (EU) invested €859 billion in its transport infrastructure [8], corresponding to €122 billion annually. Based on collected examples of similar disasters, it seems fair to assume that the failure costs equal at least 10% of the investment costs. Extrapolated to the EU, total failure costs may amount to €12.2 billion. And a conservative estimation of subsoil-related failures (about 1/3 of total failure costs) then amounts to about €4 billion annually for the EU.

Hence, geotechnical engineering plays an important role in one of the greatest challenges of modern society: continuing to provide a safe, secure, efficient and affordable transportation network for people and goods.

Vision	**Optimal geotechnical design, construction, maintenance and upgrading of transport infrastructure**		
Values	Sustainable transport infrastructure by using innovative solutions.	Available transport infrastructure by guaranteeing secure & resilient solutions.	Affordable transport infrastructure by costs optimization.
Geotechnical solutions	Reuse of soil waste. Use of enviromentally friendly materials. Minimization of ecological footprints. Retrofitting and reuse of foundations. Efficient use of geosynthetics. Decrease energy and land consumption.	Hazards mapping. Geohazards mitigation. Reliability of geostructures. Risk management & monitoring. Sustainable maintenance techniques.	Modern technologies for soil investigations, permanen monitoring and new methods for soil parameter interpretation (e.g. advanced numerical design methods, machine learning, etc.).
Strategic objectives	Develop innovative techniques and methods for reduction of ecological footprints and waste during construction	Develop innovative techniques and methods for reduction of risk for disasters & adaptation to climate change	Develop innovative techniques and methods to increase knowledge in early stages of design for time and money savings
Expected impact	30% reduction in use of raw materials. 30% increase in use of secondary materiales.	25% reduction in delays due to infrastructure maintanence or reconstruction. 25% reduction in fatalities and severe injuries due to natural disasters.	20% reduction in total cost of ownership.

Figure 2. ELGIPs vision for the future of transport infrastructure

ELGIP therefore urges policy makers, risk managers, transport planners, road and bridge engineers, among others to collaborate with geotechnical engineers at early stages when planning, building and maintaining infrastructure projects to ensure adequate information on ground conditions and soil-structure interaction.

4. ELGIPs vision

One ELGIP vision is that all transport infrastructure should aim for an optimal geotechnical design. The field of geotechnical engineering will thereby contribute to EU's ambitions of sustainability, availability and affordability (see Figure 2).

5. Practical risk management

Failure to manage risk and uncertainties can result in dire outcomes. Geotechnical engineers have the responsibility to properly assess and manage the risk of the unpredictable and the unavoidable associated with the ground conditions. As Lacasse [9] states: "*society increasingly requires the engineer to quantify and manage the risk which people, property and the environment are exposed to. The role of the geotechnical engineering profession is to reduce exposure to threats, reduce risk and protect people*".

On the path to manage risk and uncertainty, geotechnical engineers must develop innovative approaches, tools, techniques, policies, and business relationships to address impacts associated with natural and man-made threats. For example, by applying tools like hazard, reliability and risk approaches, and combining them with new digital technologies as machine learning, the geotechnical engineer can be assisted in the design of foundations and decision-making. That work must find a prominent place in geotechnical engineering education and practice, and it must become part of the research agenda, regulatory and business policies, and an expectation for business and contractual relationships.

ELGIP believes that identifying, improving, and encouraging the use of innovative geotechnical technologies during planning and design will have an important impact on the sustainability, availability and affordability of Europe's transport infrastructure in the next decade.

6. Strategic development directions

As mentioned before, one of the greatest challenges for modern society is to continue to provide a safe, secure, efficient, affordable transportation network for people and goods. This ambition includes new as well as existing transportation networks. Research, development and innovation within geotechnical engineering plays an important role in this challenge.

Based on identified geotechnical demands proposed in ELGIPs vision document "Reduction of geotechnical uncertainties for infrastructure" [10], formulated by a number of geotechnical research institutes and universities across Europe, ELGIP proposed a research agenda 2017-2015 [11] for optimized geotechnical transport infrastructure. The following development directions invite policy makers, transport engineers, risk managers, geoscientist and engineers in general to collaborate in:

- Encouraging civil engineers to more rapidly make use of new technologies.
- Promoting multi-national exchanges between disciplines for development and application of successful innovations worldwide.
- Accelerating the integration of technology through effective partnerships of government, industry, academia, and practitioners in research, learning, leadership, and application.
- Encouraging collaboration between builders/clients and geotechnical engineering researchers to identify and evaluate promising construction techniques
- Incorporating systematic risk management techniques into the evaluation of new technologies to equitably share risk and more fully embrace these innovations.
- Exploring ways to enable early and safe adoption of new technologies in codes and standards, including the process used to revise codes and standards

IOP Conf. Series: Earth and Environmental Science **710** (2021) 012069 doi:10.1088/1755-1315/710/1/012069

7. What's next?

When planning for new transport infrastructures, maintenance and retrofitting of existing ones, we urge planners and policy makers to put the money and efforts to where it makes a difference: Improved knowledge and understanding of ground properties!

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