Sustainability report of the European large geotechnical institutes platform

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State-of-the-art Report

Sustainability report of the European large geotechnical institutes platform

Rapport sur la durabilité du groupement européen des grands instituts de géotechnique

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ABSTRACT: The European Large Geotechnical Institutes Platform (ELGIP) is a group of 15 leading research organizations in geotechnical engineering that aims to promote internationally the profession and its societal relevance. One of ELGIP's objectives is to drive sustainability in geotechnical engineering and establish a common platform for sustainable practices and knowledge transfer across national borders in Europe through its working group on Sustainability. This paper summarizes the latest efforts of ELGIP's Sustainability working group (WGS), with contributions from ten national organizations in Europe. The current practice in geotechnical engineering is evaluated both qualitatively, by highlighting selected projects with significant components related to sustainability within WGS, and quantitatively, by presenting the level of involvement of the partner institutes in relation to each specific sustainable development goal (SDG) of UN's 2030 Agenda. Finally, general recommendations with respect to the future development of current practice are made based on the outcome of the evaluation. The paper demonstrates the important role that geotechnical engineering can play in achieving sustainable development goals.

RÉSUMÉ: Le Groupement Européen des Grands Instituts de Géotechnique (ELGIP) comprend 15 organismes de recherche dans l'ingénierie géotechnique et vise à élever au niveau international la profession et sa pertinence sociétale. L'un des objectifs de l'ELGIP est de promouvoir le développement durable dans l'ingénierie géotechnique et d'établir une plateforme commune pour les pratiques durables et le transfert de connaissances au-delà des frontières nationales en Europe par son groupe de travail sur la durabilité. Ce document résume les derniers efforts du groupe de travail avec des contributions de dix organismes nationaux en Europe. La pratique actuelle de l'ingénierie géotechnique est évaluée qualitativement, en mettant en évidence projets sélectionnés avec des composantes significatives liées à la durabilité au sein de ces organisations, et quantitativement, en présentant le niveau d'implication des instituts partenaires par rapport à chaque objectif de développement durable (ODD) de l'Agenda 2030 de l'ONU. Enfin, des recommandations générales concernant le développement futur des pratiques actuelles sont formulées sur la base des résultats de l'évaluation. Le document démontre le rôle important que l'ingénierie géotechnique peut jouer dans la réalisation des objectifs de développement durable.

Keywords: Geotechnical engineering; research; sustainability; knowledge transfer; collaboration.

1 INTRODUCTION

The evolution of society in relation to the sustainable development goals (SDGs) set by UN's 2030 Agenda for Sustainable Development (UN, 2015) is a very complex process easily affected by factors such as lagging policy making and implementation, or concurring crises. Rather than being independent, such factors tend to cascade and produce cumulative effects and chain reactions, given their origin in the interlaced environmental, economic, and social threads of the society. Typical examples for the past decade are the

COVID-19 pandemic or the armed conflicts, which, beyond the tremendous death tolls, cascaded in food shortage, job losses, supply chain issues, increasing energy costs, or inflation, just to mention some of their global and local effects.

Unfortunately, UN's evaluation of the current global state of progress towards the SDGs of the 2030 Agenda indicates a rather slow implementation and even regression in some specific areas, caused mainly by such interdependent crises experienced in the past years. Consequently, the fundamental questions that need a timely answer are "Where are we now?" and "Where are we heading?". Sharply defined answers to these questions can identify necessary steps required to achieve the desired progress on the path towards a more sustainable future, as shown by the Global Sustainability Report 2023 (Miranda et al., 2023).

Experience has shown that sustainable progress is impossible while focusing only on specific areas of interest. The compounded risks affecting the various interlaced threads of the society call for a holistic approach in evaluating the current state and planning mitigation and development strategies. Collective effort at all levels is essential, along with a clear path of knowledge transfer between society and decision-makers.

In this context, the role of research cannot be overstated, as it has the potential to provide valuable insights and guidance in decision-making processes to achieve the SDGs. Catalysed by the complex interplay of the compounded risks projected on interdependent societal layers, the research interest related to UN's SDGs has advanced significantly in the past decade, and an exponentially increasing number of relevant scientific contributions has been generated (Figure 1).

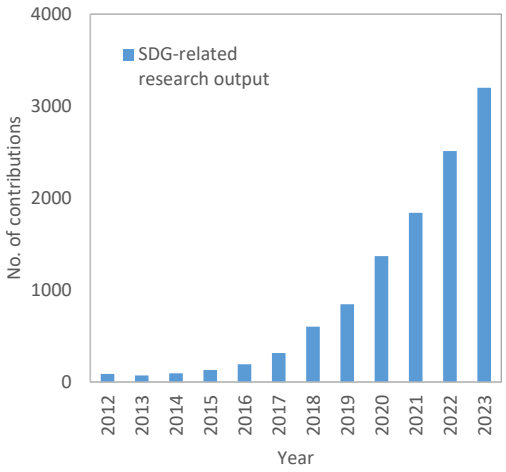

Figure 1. Scientific output relevant to the SDGs generated in the past decade (SCOPUS, 2024).

According to SCOPUS the contributions cover 27 different fields of interest, out of which social sciences, environmental science, and engineering are the most relevant ones, collectively attracting a total number of contributions comparable to the other fields cumulated.

Geotechnical engineering, as part of the broader engineering area and with ramifications in environmental sciences, has the potential to contribute significantly to the advancement of UN's Sustainability Agenda. The current paper provides a summary of the sustainability status in geotechnical engineering research reported by members of ELGIP, with the intent to encourage further development in this direction, catalyse the knowledge transfer from ELGIP to the decision-makers, and accelerate the achievement of the relevant SDGs.

2 METHODOLOGY

The results presented herein were obtained by processing the answers provided by the members of the Working Group Sustainability (WGS) of ELGIP to three main questions: (i) "What is the current strategy or policy for sustainable development in your organisation?" (ii) "How do you work towards specific sustainable development goals (SDGs) from a geotechnical perspective?" (iii) "What is the ongoing and recently finished work of relevance to sustainability?" The detailed input can be found in the recently published report of ELGIP (Christiansen et al., 2023).

Out of the 15 ELGIP members, 10 organisations from 10 European countries (Figure 2) are part of WGS and provided input on their current strategies and policies for sustainable development, and their specific activities and projects towards achieving sustainability goals from a geotechnical perspective. These organisations are Spanish National Public Works Research Centre (CEDEX), Czech Technical University in Prague (CTU), Swiss Federal Institute of Technology in Zürich (ETHZ), Norwegian Geotechnical Institute (NGI), Polish Geological Institute (PGI), Politecnico di Torino (PoliTo), Swedish Geotechnical Institute (SGI), Technical University of Darmstadt (TUDa), Université Gustave Eiffel (UGE), and University of Maribor (UM).

Initially, a qualitative evaluation of the activities of WGS members is conducted. The main relevant topics are identified using approximately 60 recent projects provided by each institute and classified in relation to sustainable development. Subsequently, most significant projects (Table 1) are briefly described to

showcase their relevance to sustainability. Moreover, the leading areas of interest for future development of geotechnical engineering within the framework of sustainability are identified and briefly discussed.

In the next step, the activity is evaluated quantitatively by roughly assessing the level of involvement in relation to the SDGs. The assessment is performed by determining the number of institutes of WGS actively working towards each SDG. The quantitative evaluation is put into perspective using the global level of achievement of the SDGs estimated by averaging the realisation of the specific targets presented by Miranda et al. (2023) for each SDG in UN's Global Sustainability Report 2023.

Figure 2. European countries represented in the WGS of ELGIP.

3 RESULTS

3.1 Qualitative evaluation of current activities in relation to sustainability

The qualitative evaluation revealed four topics in which WGS members are involved: (1) climate change, (2) environmental impact of (geo)structures, (3) circularity and reuse of geomaterials and (4) social sustainability (Table 1). In terms of SDGs, the most relevant ones, attracting most of the activity in geotechnical engineering are:

- SDG-7 - Ensure access to affordable, reliable, sustainable, and modern energy for all
- SDG-9 - Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
- SDG-11 - Make cities and human settlements inclusive, safe, resilient, and sustainable
- SDG-12 - Ensure sustainable consumption and production patterns

Further SDGs were reported by the WGS members covering almost the entire spectrum of goals, with the exception of Poverty Eradication (SDG-1), Zero Hunger (SDG-2) and Peace, Justice and Strong Institutions (SDG-16). The apparent irrelevance of these goals to geotechnical engineering could be explained by a rather strict interpretation of their definitions by the WGS members. Given the interdependent nature of SDGs, geotechnical engineering makes indirect contributions to these seemingly unrelated goals by addressing societal needs relevant to SDGs 7, 9, 11 and 12 with effective solutions.

Moreover, less technical goals such as gender equality (SDG-5), decent work and growth (SDG-8), and reduced inequalities (SDG-10) are, on the one hand, an essential part of the intramural organisational strategies of the institutes often including established and dedicated internal strategic-operational units. On the other hand, these aspects can be found in the implementation of the various projects, in which the institutes are involved.

As an example, project GEOLAB (GEOLAB, 2021), involving 11 experimental installations from nine European countries with the purpose of addressing challenges faced by the Critical Infrastructure of Europe (relevant to SDGs 7, 9, 11, 12), is committed in its implementation to SDGs 5, 8 and 10. More specifically, the project contributes to the reduction of inequalities between potential researcher groups with unequal financial and technical means (SDG-10) by offering free access to experimental infrastructure. Besides the essential role of scientific merit and relevance of the intended research, the free access is granted by taking into account the participation of female (SDG-5) and early stage (SDG-8) researchers, which tend to be under-represented in such projects. Moreover, the specific composition of the management team and international advisory board of GEOLAB was set-up to meet minimum criteria related to gender balance.

Further on, the activity of WGS members related to ongoing and recently completed projects relevant to sustainability is briefly summarized to offer a clearer overview of the specific actions currently driving the progress towards the SDGs at the European level. Table 1 provides a summary of some major projects mentioned by the WGS, categorized by topics.

Table 1. Collaborative European projects relevant to sustainability divided into topics.

Topic	Projects
Climate change	GEOLAB (GEOLAB, 2021)
Environmental impact of (geo)structures	SENSE-ACT (SENSE, 2023)
Circularity and reuse of geomaterials	ARV (ARV, 2022), URGE (URBACT, 2022), CINDERELA (CINDERELA, 2018)
Social sustainability	FP3-IAMRAIL (Europe's Rail, 2022) RID (RID, 2023) REMEDY (Langford et al., 2021) 2015 Gorkha Earthquake Relief (Amdal et al., 2018)

For topic (1) climate change, most projects listed by WGS members focus on three main sub-topics: (i) identification/detection/assessment, mapping and visualisation, (ii) prevention, and (iii) mitigation/adaption strategies against natural hazards (e.g. landslides, flooding) associated with climate change (Insana et al., 2021).

In terms of collaborative involvement at European level on this topic, the already mentioned project GEOLAB (ongoing) (GEOLAB, 2021) stands out as a one-stop-shop of high-end physical research infrastructure. The aim of the project is to address challenges associated with climate change faced by the critical infrastructure of Europe by facilitating ground-breaking research and innovation through experimental testing. In this sense, a wide spectrum of problems related to climate change, which do not focus necessarily on one of the sub-topics mentioned above, are investigated. Furthermore, geotechnical institutes from France, Italy, Norway, and Sweden are involved on a relatively independent basis with the topic of nature-based solutions (NBS) in relation to coastal geotechnical infrastructure, river dykes, large embankments, land use and land cover. The use of NBS for both prevention and mitigation/adaption strategies against the impact of climate change is explored in the relevant projects.

Within topic (2) environmental impact of (geo)structures, more than 20 ongoing or recently finished projects were indicated by the WGS members, dealing with subjects such as: life-cycle assessment (LCA) and eco-geo-analysis tools for geotechnical structures, management of tailings storage, construction on contaminated soils, design methods achieving the reduction of carbon footprint of (geo)structures without compromising safety, geospatial tools for site optimization and environmental impact reduction, thermal energy, and geo-structures. The high number of nationally funded projects is an indication of the strong interest of local decision-makers in the various applications of this topic in relation to geotechnical engineering.

A notable example of collaborative involvement in this topic is the project SENSE-ACT (ongoing) (SENSE, 2023), which involves 14 partners from 10 countries (four of which are outside Europe). The main objective of the project is to demonstrate reliable and cost-efficient CO2 storage solutions using ground surface deformation detection combined with geomechanical modelling and inversion to provide information on pressure distribution and hydraulic behaviour of storage sites.

Topic (3) circularity and reuse of geomaterials includes projects mostly concentrated around three sub-topics: (i) re-use and life-cycle extension of existing structures, (ii) circularity of materials and (iii) management of waste and earth materials. In this area of interest, multiple projects stand out by their large-scale collective effort at European level.

Project ARV (ongoing) (ARV, 2022) involves 35 partners from eight European countries and aims at implementing six large-scale demonstration projects of climate positive circular communities and subsequently developing guidelines and a policy framework for future energy-efficient, circular, and digital solutions in the construction industry.

Project URGE (recently finished) (URBACT, 2022) involved nine European cities, which committed to exchange knowledge and experience, while implementing integrated urban policies focused on circularity in the construction tasks. Similarly, project CINDERELA (recently finished) (CINDERELA, 2018) involved 13 partners from seven countries and aimed at developing and demonstrating a new business model for companies in setting up successful circular economy business cases based on waste-to-resource opportunities. The project provided full-service assistance in terms of know-how for manufacturing and application of secondary raw materials in buildings and civil engineering works.

The last topic identified during the qualitative evaluation of the activity of WGS members is (4) social sustainability, with subtopics such as sustainable communities and infrastructure, or improved living conditions. One of the main projects reported here is FP3-IAM4RAIL (ongoing) (Europe's Rail, 2022), involving 94 partners at European level. The project aims to provide innovative technical requirements, methods, and solutions to minimise lifecycle costs and extend service life while meeting safety requirements and improving the reliability, and capacity of the railroad system. As expected for such a

large project, its impact extends beyond the topic of social sustainability. An interesting aspect investigated is the use of alternative materials in the railway track section, a typical application of the topic related to circularity and reuse of materials mentioned before.

Further projects worth mentioning in this topic are: (i) the earthquake relief project (finished) (Amdal et al., 2018) supported by FORUT, NGI and Engineers Without Borders in Norway, providing geotechnical assistance for the reconstruction of primary schools in the areas affected by the 2015 earthquake from Gorkha (M7.8) in Nepal; (ii) the RID project (ongoing) (RID, 2023) aiming at developing safe infrastructure by up-to-date guidelines for investigation and selection of soil improvement solutions for national roads and motorways in Poland; (iii) the REMEDY (recently finished) project (Langford et al., 2021) aiming at reducing the risk of damage to neighbouring structures caused by groundworks during and after execution of a project.

The qualitative evaluation of the current activities of WGS members provided the opportunity to explore some of the main directions for future development in geotechnical engineering in relation to sustainability. In this context, the first identified area of interest is circularity. The circular use of materials and structural elements (e.g. existing foundations) is already engaging the geotechnical community and is expected to generate even more interest while new methods for reusing, recycling and repurposing of construction materials are being developed.

A further area of interest is the use life-cycle assessment (LCA) in geotechnical design. This is already established in general product development, where the evaluation of environmental impact and costs are done using LCA. Nevertheless, this concept has not been extensively addressed and used in geotechnical engineering. The implementation of an LCA-based perspective is expected to optimize geotechnical design and increase its sustainability levels.

Energy optimization is a further area of interest expected to gain more traction in the years to come, considering the intensive use of energy in geotechnical works and the potential of improving associated processes in terms of energetic efficiency. In addition to sustainability concerns, the recent European energy crisis resulting from the conflict between Russia and Ukraine underscores the critical importance of efficient energy use across all sectors.

Sustainability assessments are expected to become more important in the decades to come. With the second generation of Eurocodes to be published and implemented at national level roughly by the end of 2027, sustainability will be one of the elements that must be considered during design of geotechnical structures. New methods will be required to evaluate projects from another perspective, by taking into account factors such as impact on environment and economy, equality and social justice.

Finally, yet importantly, nature-based solutions (NBS) emerged as a further area of interest for future developments on geotechnical engineering. On the backdrop of sustainability enhancement of geotechnical structures provided by the second generation of EC7, the use of renewable resources, environmentally friendly materials calls for implementation of NBS for a wide range of problems. Already attracting attention in countries with extensive coastal exposure (France, Italy, Norway, Sweden), where the effects of erosion processes can be mitigated using NBS, the topic is expected to become more relevant in further areas of geotechnical engineering.

As briefly mentioned before, the identified areas of interest for future development overlap with the general rules, measures and strategies for sustainability that will be included in the second generation of Eurocodes relevant to geotechnical engineering. This is a clear confirmation of the significance of sustainability at European level, and an indication of the ongoing common efforts of the relevant national institutions to promote this aspect in geotechnical engineering.

3.2 Quantitative evaluation of current activities in relation to sustainability

The results of the qualitative evaluation presented in the previous section demonstrate that the WGS members generally have holistic strategies in terms of sustainability, contributing with their activities and organisational strategies to the entire spectrum of SDGs. However, the focus of this paper is more on the activities of the WGS members and their specific projects with outcomes influencing the local, national and global achievement of the most relevant sustainability goals.

On average, each WGS member reported most of their projects as relevant to five out of the 17 SDGs of the 2030 Agenda, indicating a high level of commitment to sustainability, which goes beyond the sphere of science and technology. Figure 3 shows the distribution of the cumulated self-assessed activity of WGS members along the entire range of SDGs. As mentioned in the previous section, the current activity is mostly concentrated on topics such as affordable and clean energy (SDG-7), industry, innovation and infrastructure (SDG-9), sustainable cities and communities (SDG-11), and responsible consumption and production (SDG-12). The emphasis on the

specific SDGs is not a surprise, considering the specific character of applications of geotechnical engineering. Nevertheless, it is still unclear to what extent this is caused by a spatial variation of focus and development among European countries and how much it originates from a rather subjective interpretation of the SDG definitions.

In addition to the activity distribution, Figure 3 displays the estimated level of achievement for each SDG. On average, the current global progress towards all SDGs rates at 2.8 out of 5, which means that the current state is far from the final target. Generally, the influence of the recent crises such as the COVID-19 pandemic, the sharp increase of cost-of-living, armed conflicts and natural disasters can be clearly seen in the relatively low level of achievement combined with significant recessive trends outlined in the UN report.

Interestingly, SDG 9 related to industry, innovation, and infrastructure, which displays the highest level of achievement, is the same goal that attracts most activities and projects of WGS members (i.e. all participating institutes have reported project with outcomes contributing to this goal). In this context, a correlation can be seen between increased activity of relevant stakeholders, such as the geotechnical institutes in this case, and an increased level of achievement. The high number of projects also confirms the increased research and development spending from the part of the decision-makers acknowledged by Miranda et al. (2023).

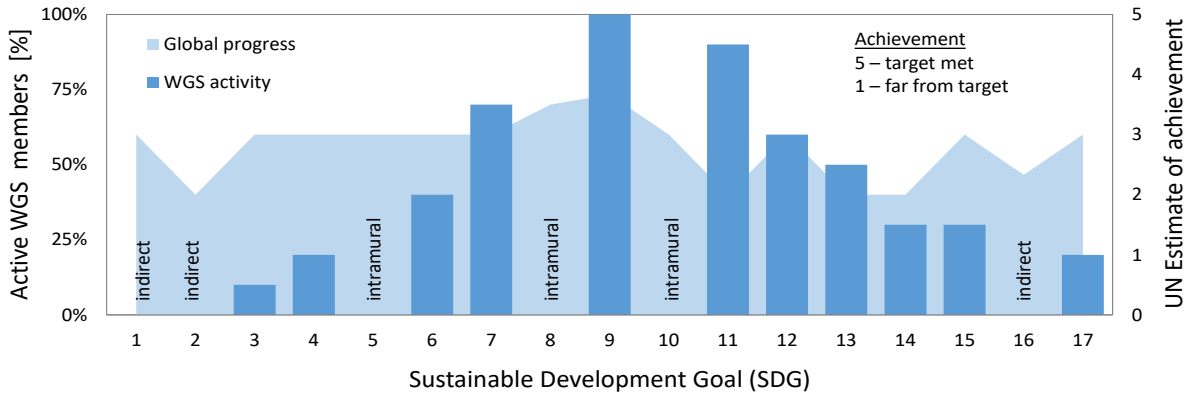

Figure 3. Involvement of WGS members in SDGs and UN estimated achievement according to Miranda et al. (2023).

4 CONCLUSIONS AND RECOMMENDATIONS

In the assessment of the sustainability status of ELGIP approximately 60 projects from 10 European geotechnical institutes were analysed. The assessment included a qualitative and quantitative evaluation of the activities of the institutes in relation to sustainability.

The qualitative evaluation of the projects indicates that geotechnical engineering can play a significant role in sustainable development. The four main sustainability-related topics identified in the assessment include projects with direct relevance to 14 out of the 17 SDGs of UN's 2030 Agenda for Sustainable Development. Nevertheless, the number of institutes participating in the evaluation is a strong limitation of the results presented herein. Consequently, more data with a higher level of granularity is required to prove clearly that the wide range of SDGs to which WGS members contribute is the result of the spatial variation of focus and development among European countries and not just a consequence of the subjectivity of the institutes while interpreting the description of the goals.

Various institutions may hold different perspectives regarding their contributions to SDGs. The self-assessed extent of the contributions strongly depends on the acquaintance with a goal definition: a cursory understanding of the goal might lead to a more reduced self-assessed contribution, whereas a more thorough one could yield a different conclusion. This complexity is a challenge in assessing an institution's impact on the SDGs solely through their self-reported alignment with specific goals.

Furthermore, the qualitative evaluation revealed the importance of pursuing less technical SDGs in the definition, organisation, and implementation of projects (e.g. gender balance targets, social inclusion measures). In this way, sustainability levels can be improved irrespective of the size and technical scope of the project.

Although not specifically analysed in this paper, the intramural adoption of a sustainability perspective at the organisational level of the institutes is a further important contribution towards a more sustainable community and has the potential to add the same perspective to the activities of researchers steering them towards more sustainability-oriented topics.

The quantitative evaluation of the projects confirms the holistic approach of the WGS members towards sustainability. Nevertheless, the limited amount of data collected and compiled in the assessment represents a limitation of the general applicability of the results, as already mentioned in the case of the qualitative analysis.

The correlation observed between the concentrated activity of the institutes towards SDGs 7, 9, 11 and 12, and the increased level of global achievement reported by Miranda et al. (2023) demonstrates the positive effect of collective effort. Moreover, broadly defined collaborative projects have the potential to contribute to multiple SDGs and to attract more funding. In this context, collaboration proves to be the key to a successful sustainable approach, and it is highly recommended in future projects, considering that sustainability-related challenges are global rather than national.

Finally, yet importantly, the results showed that increased research and development spending generates a greater number of projects in a specific area of interest, and consequently leads to a higher level of achievement of relevant SDGs. In this sense, reinforcing cross-network dissemination between research institutes, decision makers, funding agencies, businesses, and society is highly recommended. This can be done both nationally, in the case of individual WGS members, and internationally at European level, in the case of the entire ELGIP consortium, by using simple tools such as regular sustainability status reports as a basis for dialogue.

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