About the future of geotechnical engineering: a view from South America

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ABSTRACT
What is going to be the geotechnical engineering role in future generations? What challenges Geotechnical Engineers will have in the next 50 years? What are the current and future needs of societies in developing countries in relation to unsolved problems related with Geotechnical Engineering? These and similar questions triggered the author´s thoughts associated to where geotechnical engineering is going to in terms of research, education, design, and practice fields. This paper summarizes the author's feelings enriched by significant interactions and discussions with graduate students and colleagues; there is no intention to make an apology of the future, instead, the purpose is to trigger discussions between geotechnical engineers with focus on the relevance and role of our profession in a changing world.

RESUMEN
¿Cuál será el rol de la ingeniería geotecnica en las próximas generaciones? ¿Cuáles son los desafíos que deberá enfrentar un ingeniero geotécnico en los próximos 50 años? ¿Qué necesita y necesitará la sociedad en referencia a problemas por resolver relacionados con la geotecnia? Estas son algunas de las preguntas que motivaron el pensamiento del autor sobre hacia donde se dirige la ingeniería geotecnica en los campos de investigación, educación, diseño y tendencias futuras. Este artículo refleja el pensamiento del autor, enriquecido por valiosas conversaciones con colegas y estudiantes de posgrado, que han permitido desarrollar ideas básicas que no pretenden ser una apología del futuro sino por el contrario despertar el interés de la sociedad geotécnica en discutir la relevancia y el rol de la geotecnia frente a un mundo cambiante.

1 GEOTECHNICAL ENGINEERING 2010-2020

The near future of Geotechnical Engineers can be easily predicted by analyzing the research and engineering practice of young Geotechnical Engineers. The best way to do this is looking at the content of papers published in Asian, European, South-American, African and World Young Geotechnical Engineers Conferences. Young professional Engineers, Master and Ph.D. students attended these events and discussed hot topics within the geotechnical field. In most cases, these works are related to research projects or industry proposals that reflect current and near future needs.

The 3rd South-American Conference of Young Geotechnical Engineers, held in Córdoba (Argentina) in 2009 brought together over 86 participants from 9 different countries. There were 51 articles organized in six different sessions: soil mechanics, foundation engineering, environmental geotechnical engineering, site and laboratory investigations, embankments and retaining structures, and computational geomechanics. The main topics of papers were related to both classical and innovative geotechnical problems (Table 1).

Contributions summarized in Table 1 show that some topics little considered in the last century have become of relevance, capturing the attention of Geotechnical Engineers. For example, problems related to waste disposal, contaminant fate and transport, micromechanical analysis, soil improvement and soil stabilization techniques have similar relative importance than classical soil mechanics and foundation engineering aspects.

Table 1. Topics that young geotechnical engineers are working on in South America

TOPIC	RELATIVE IMPORTANCE
Geo-environmental problems	24%
Soil behavior and properties	24%
Ground Improvement and geosynthetic	11%
Seepage flow	5%
Shallow and deep Foundations	19%
In-situ tests and soil dynamics	6%
Constitutive models and numerical methods	11%

Some diversity can be observed looking at what is happening in the rest of the world. Table 2 summarizes the relative amount of contributions of different geotechnical topics received in the Fourth International Young Geotechnical Engineers Conference, held in Alexandria (Egypt) in 2009. More than 83 Geotechnical Engineers attended this conference coming from 42 different countries around the world (all regions in which the ISSMGE is divided into were represented).

A deeper analysis of the focus of papers presented in these two conferences reveals similarities and differences. The main similarities consist of methodologies, used laboratory facilities, revealed creativity and innovation, and employed research tools. Most significant differences identified were the number of

works related to environmental problems and seepage in South America (29%) in comparison with the rest of the world (10%). Similar trends were observed in the case of constitutive and numerical methods. Exploring the central point of papers becomes clear that these trends are related to unsolved problems in developing countries that are just beginning to be considered of relevance within the geotechnical field in South American countries.

Table 2. Topics that young geotechnical engineers are working on in the world

TOPIC	RELATIVE IMPORTANCE
Soil behavior and properties	16%
Ground improvement	19%
Seepage flow and environment	10%
Landslides and slope stability	13%
Deep foundations	16%
Tests and earth retaining structures	16%
Soil-structure interaction	10%

Another similarity between the topic that young Geotechnical Egineers are working on in South America and the rest of the World is that few works are based on the use of Standard Penetration Test (SPT). However, there is a considerable amount of works that somehow focuses on the use of SPT in regular local and international conferences. This difference evidences that geotechnical engineers may consider in the future new areas as important as those classically covered in soil mechanics and foundation engineering. The first evidence that this phenomenon is already happening is that topics are more specialized at the present time. This can also be evidenced in the increasing amount of specialized conferences and technical committees in the ISSMGE.

2 GEOTECHNICAL ENGINEERING 2020-2070

There is no doubt that the type of geotechnical problems are changing with time. Consequently, new studies, tests, analysis, strategies and methodologies have to be developed to provide smart solutions to present and future needs. The main constraint to achieve this is that "geotechnologists are for the most part not prepared for these changes" (Long et al. 2010).

2.1 Research Trends

Research trends should change with the purpose of finding novel solutions to new problems. Then, researchers will pay attention to different topics in the future given that research trends depend on time and space. Few changes are expected for the design process given the relevance of previous solutions and engineering practice on the design process itself. However, the type of activities and problems that geotechnical engineers deal with will change in the next 50 years.

Previous knowledge is going to become even more relevant in the future. Nowadays numerical analysis and the capability of modeling different geotechnical problems have reached a level of sophistication never thought in the last century. Also, new testing methods, with the aid of technology, make possible to obtain reliable data from soils and rocks. However, there are still many limitations in performing site characterizations good enough to capture spatial and temporal variability of porous media and groundwater properties.

Geotechnical engineers may build three-dimensional (3-D) models without a significant effort but obtained results may not always be good enough. Computational geomechanics advanced faster than our capability of feeding these models. More research is needed to obtain low cost and reliable soil properties from in-situ tests. This will allow including the spatial variability of soils, the correlation length of soil properties and the better characterization of non-linear and anisotropic behaviours. This may lead to two different approaches, one deterministic and the other based on reliability based analysis and in both cases will help in reaching unique criteria for the solution of many geotechnical problems (De Mello 1999).

Also, more efforts in the study of local soils can be required in the future (e.g. Rocca et al. 2006, Terzariol 2009). Learned lessons from several researchers and practitioners will help to generate free access databases of existing ground information (e.g. geotechnical maps, collapsibility maps, erodibility maps, land slide risk maps, etc.).

This may help to move faster toward new tendencies in geotechnical engineering including the characterization of spatial variability of soils, behaviour of fractured media, coupled phenomena (e.g. thermal-bio-chemical-mechanical processes), and interdisciplinary tasks related to the new challenges of this century (Simpson and Tatsuoka 2008, Francisca et al. 2011, Yeboah and Burns 2011).

2.2 Construction Needs

The role of geotechnical engineering in developed and developing countries is going to be related to the need of new and modern civil infrastructure. However, the profession is always related to industry needs and this becomes a limiting factor in the case of developing countries.

As time goes on, more people live in urban areas. This has tremendous consequences due to the generation and accumulation of waste, the change in the land use and the pollution of air, water and soil. The solution to these problems is somehow related to the geotechnical engineering profession.

Most research and professional activities will be constrained by the need of developments in congested urban areas, recycling buildings and foundations, and designing and constructing geo-structures in difficult site conditions (e.g. unstable soils, steeper slopes, erosion problems, previous constructions, etc.), and geoenvironmental issues. However, in South America, the geotechnical engineering profession will deal more with urgent needs than with new challenges. In particular, geotechnical engineers will be mainly involved with waste management, civil infrastructure development and mitigation of natural hazards, all subjects extensively worked since the last century in developed countries (Shackelford 2005, Long et al. 2006).

2.3 Technology, Population and Energy

More sophisticated geotechnical analysis can be performed nowadays. This trend will continue in the future and with the aid of science will be possible to improve problem identification and developing of efficient and safe construction for the changing world conditions (Chowdhury and Flentje 2007, Terzariol 2011).

By 2050 the world population will exceed 9.3 billion people. This will clearly produce demand of not only food but also civil infrastructure. Geotechnical engineers will play a fundamental role in defining strategies for the construction of underground facilities, designing structures in limited space and maybe under unfavourable site conditions or higher risk, planning strategies for the disposal of waste, developing new geotechnical construction methods, etc.

A very particular situation can be observed with the actual relation between development and fossil fuels demand. More than 80% of the world's energy derives from fossil fuels. Given that population growth and energy demand are correlated with each other, new strategies are going to be developed in the renewable energy sector (Yun et al. 2011). Consequently, offshore geotechnical engineering will gain relevance in the next decades (Randolph 2005), as well as the development of new strategies for carbon capture and storage (Boyd 2008). Also, energy geotechnology, wind farms and storage systems will also demand significant new knowledge from geotechnical engineers (Santamarina 2011).

2.4 A Changing World: New Needs

The use of fossil fuels produce environmental and health problems and is also somehow related to global climate change. Then, new research trends should include interdisciplinary works focussed on the development of new renewable and emission free energy systems.

The scope of the geotechnical engineering profession will expand in the near future as a consequence of the demand of new Earth problems, such as global change, the increase of fresh water and energy demand, population growth and the need of rational and optimal use of natural resources in order to achieve a sustainable development.

In order to be protagonists looking for solutions to the new demands of this changing world, Geotechnical Engineers will have to improve the understanding of soil behaviour. One possibility to achieve this consists on finding the way to explain emergent macroscopic behaviour and engineering properties of soils from the understanding of microscopic physical and chemical properties (Long et al. 2006). Collaboration between researchers and professional geotechnical engineers will be of fundamental importance to find novel and creative solutions from both the theory and practice paradigms defined by Vick (2002) (Rocca 2009).

2.5 Research and Education Role in the Formation of Geotechnical Engineers for the Next Century.

Industry plays a primary role in engineering research and, at the same time, requires research in order to develop new geotechnical construction methods as well as to develop modern and safer geotechnical analysis. This interdependence between research and engineering application become of fundamental importance to build the knowledge and find solutions to the new society's needs.

The coupling between research and teaching will continue and may become even more significant in the next 50 years. The Royal Academy of Engineering (2003) highlights that "*academy cannot maintain excellent standards of teaching in an applied subject such as engineering in an higher education institute that is not research active*". This is critical given the role of higher education institutions in preparing the professionals for this millennium (Duderstadt 2008). Considering this, research and development in industry need to be stimulated, and government funding available for research and technology development should increase in South America in the next 50 years.

2.6 Risk of Predicting the Future

There is always a big risk of mistake in predicting the future. At the same time, geotechnical engineering can significantly contribute to find creative solutions to current and future needs of this changing world. We must build our future reinventing geotechnical engineering in order to play a key role in developing a safer and more sustainable world.

3 CONCLUDING THOUGHTS

Important changes are observed in the world as consequence of new needs that emerge caused by population growth and global climate changes. Geotechnical Engineers in the next years have to be prepared to expand their roles to find solutions to civil infrastructure needs, for the mitigation and prevention of earth system problems related to global changes, increased energy demand, and emission and waste management and disposal. This will require of new geotechnical construction methods and surely of new research strategies as well as an integrated and multi-disciplinary approach in order to find novel and creative solutions. Practitioners and researchers should work together if we desire geotechnical engineering to have a leading role in defining strategies and designing solutions to the new challenges of this century.

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