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# About a model to increase competitiveness efficiency and profits of the geotechnical construction industry

## À propos d'un modèle pour augmenter la compétitivité, l'efficacité et les profits de l'industrie de la construction géotechnique

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ABSTRACT: As a subspecialty within the construction industry, the geotechnical industry is no stranger to the factors that hinder productivity on construction projects e.g., it's a very inefficient marketplace to coordinate communication, its geographically dispersed, value is heterogeneously scattered, every project is custom made and hyper local and stakeholders of projects are not centralized, giving way to the subcontractor system. These factors result in a fragmented and stagnated geotechnical industry, producing projects that deviate from the economical, technical, and executional optimum.

Open Innovation can help to reduce the impact of these factors because the right approach to handling, sharing and using innovation originated elsewhere, can expose weaknesses and uncover better practices. A revision of the mechanism through which Open Innovation happens is important to understand that improving intelligence, communication protocols and fulfilment processes are critical for revitalizing and advancing our industry. For instance, several experiences in test fields and loading tests show that the overdesign of deep foundations is a common practice, even though it's unknown at the moment of the design. We want to make the case for combining the expertise of several stakeholders as a means to reduce inefficiencies like overdesign.Based on the examples we present, the basic model we propose was improved through experiences. The involved stakeholders are a specialized designer (SRK), a technology provider (EBPanama), two construction companies in two countries (INCOTEC and EMBRE) and an instrumentation company (INGERTOOLS). The goal is to have a tool to share, first, with members of Corporate Associates.

RÉSUMÉ : En tant que surspécialité dans l'industrie de la construction, l'industrie géotechnique n'est pas étrangère aux facteurs qui entravent la productivité des projets de construction, par exemple, c'est un marché très inefficace pour coordonner la communication, sa dispersion géographique, sa valeur est dispersée de manière hétérogène, chaque projet est fait sur mesure et les acteurs hyper locaux et les acteurs des projets ne sont pas centralisés, laissant la place au système de sous-traitance. Ces facteurs aboutissent à une industrie géotechnique fragmentée et stagnante, produisant des projets qui s'écartent de l'optimum économique, technique et d'exécution.

L'innovation ouverte peut aider à réduire l'impact de ces facteurs, car la bonne approche de la gestion, du partage et de l'utilisation de l'innovation provenant d'ailleurs peut révéler des faiblesses et découvrir de meilleures pratiques. Une révision du mécanisme par lequel l'innovation ouverte se produit est importante pour comprendre que l'amélioration de l'intelligence, des protocoles de communication et des processus d'exécution est essentielle pour revitaliser et faire progresser notre industrie. Par exemple, plusieurs expériences dans les champs de test et les tests de chargement montrent que la sur-conception des fondations profondes est une pratique courante, même si elle est inconnue au moment de la conception. Nous voulons plaider en faveur de la combinaison des expertises de plusieurs parties prenantes afin de réduire les inefficacités telles que la surconception.

Sur la base des exemples que nous présentons, le modèle de base que nous proposons a été amélioré au fil des expériences précédentes. Les parties prenantes impliquées sont un concepteur spécialisé (SRK), un fournisseur de technologie (EBPanama), deux entreprises de construction dans deux pays (INCOTEC et EMBRE) et une société d'instrumentation (INGERTOOLS). L'objectif est d'avoir un outil à partager, d'abord, avec les membres de Corporate Associates.

KEYWORDS: Critical state theory; direct simple shear; triaxial, discrete element method; granular material.

## 1 INTRODUCTION.

Considering the thoughts of ISSMGE through the Corporate Associates for the development of the geotechnical industry goals, in this paper we present experiences to improve the value chain of the industry (from basic engineering and soil investigation to construction, testing and reporting results). By relying on the openness of communication and expertise exchange, benefits for all companies involved increase. The model should be created by accessing and using the Corporate Associates skills and knowledge to improve our results as a subcategory of the construction industry in general.

The question that we try to answer in this paper is: "How to leverage open collaboration to increase the learning speed and profit of the geotechnical industry in all its levels and become more competent?"

In the message by the FIEC President, Dr. Thomas Bauer, he says: "We aim to ensure the cooperation required between all parties concerned for the successful management of businesses for their employees, owners and other stakeholders."

What drives companies to cooperate? We identify two big incentives, namely, commercial and technical. Commercially speaking, collaboration leads to a reduction of execution costs and times, improves and expands the offer of products or services, increases sales and achieves competency to execute projects that none of the companies in the cooperation group would be able to execute on their own. Technically speaking, collaboration leads to risk reduction of designed solutions, increases the usage of new technologies, increases Quality Assurance & Quality Control and reduces the carbon footprint. For instance, the cooperation between Research Institutions and Engineering Companies tends to be triggered by the need to develop novel solutions to pressing problems or improve existing technologies. In the Geotechnical field, the need for cooperation increases, as technological development and the improvement of existing technologies often require adaptations and adjustments to the geological-geotechnical context due to an increasing degree of complexity.

The specialty of deep foundations works in an inherently unpredictable environment: the soil. Regardless of soil investigations, data will never be available for 100% of the soil mass. The sector is dependent on high tech and specialized skills to be reliable. In a deep foundation setting, all the following items need to converge:

-Soil investigation
-Engineering design
-Machinery
-Monitoring & QAQC
-Environmental impact

Before we go into the case study, we need to better understand Open Innovation.

Open Innovation requires view of the company in relation to its ecosystem instead of a view based on its internal resources. In a resource-based view, a company is conceived as a combination of several business units and/or subsidiaries that operate in isolation. Profits are created through the usage of resources and skills possessed and controlled by the focal company.

In a relational view, the focal company is considered as being embedded in a web of relationships. The focus shifts from a focal firm to an ecosystem of internal and external players. Profits are created through resources shared among ecosystem members.

When companies operate with a relational view, the expectancy of profits for all involved parties is higher than what each party would expect in isolation because the exchange relationship increases opportunities and efficiencies. Increased profits can come from complementary resources endowments (distinctive resources of partners that in combination generate greater results than the sum of these resources in isolation), interfirm relation-specific assets (assets that become special and unique when several companies combine their skills), interfirm knowledge sharing (interaction that permit the transfer, recombination or creation of specialized knowledge) and effective interfirm governance (governance mechanism between companies to minimize transaction costs between them).

The concept of relational view proves that cooperation among companies is important to create results that are superior to the sum of results that those companies could create in isolation. But how is this process of cooperation actually executed? Open Innovation is the framework to structure it.

In the traditional closed innovation model, innovation flows through a closed funnel with 3 main stages, namely, ideation, R&D and commercialization. For an innovation to go from ideation to commercialization, it moves in a linear process through "stage gates" that validate or disprove its advancement. This approach relies solely on internal resources and capabilities. Resources, knowledge, and skills elsewhere are not considered. The principles governing a closed innovation process consider that (1) the focal company employs the smartest people in the specific field, (2) to profit from R&D, the focal company must discover, develop and commercialize the innovation, (3) there is a rush for being first-to-market, (4) the focal company is solely responsible for creating quantity and quality of ideas and (5) tight control of IP is critical for success.

Open Innovation flips the notion of "the company as an isolated entity to develop innovation" to "the company within a ripe ecosystem to develop innovation". The principles governing Open Innovation consider that (1) there are many smart people working elsewhere, (2) the company needs to access smart people within the company as much as outside of it, (2) R&D does not have to originate necessarily inside the company to profit from it, (3) first-to-market is not the only competitive advantage - coordination and execution of business models play a major role, (4) internal and external ideas should be used and (5) the company should profit from others using its IP as much as acquiring others IP, whenever possible.

For the case of Open Innovation, the 3-stage innovation funnel (ideation, R&D and commercialization) also applies, but the funnel is open, permeable to internal ideas going out and external ideas coming in. An increase in target markets is expected because the open funnel leads to serving not only current market, but potentially adjacent markets to the current niche or new markets outside of the current niche.

The range of Open Innovation can be described with a 2x2 matrix:

Based on the exposed definitions of Open Innovation, we now turn to the case study to see the theory in action.

| | Inbound Open Innovation | Outbound Open Innovation |
|---|---|---|
| Non-monetary | **Sourcing**<br>-External sourcing of ideas from users, universities, suppliers, competitors, start-ups, etc. | **Revealing**<br>-Free sharing of ideas and knowledge with the public or selected external partners. |
| Monetary | **Acquiring**<br>-Licensing external IP<br>-Purchase external know-how (firms or talent)<br>-Invest in external tech developments through mechanisms like corporate venture capital | **Divesting**<br>-Creating spin-off companies to develop and commercialize new technologies, services and products.<br>-Out-license own IP<br>-Sale of internal know-how and IP |

## 2. THE CASES BEHIND THE MODEL

### 2.1. *The expander body (EB)*

The EB technology was invented in Sweden by the Engineer Bo Skogberg in the 1980s. A Swedish company, SOILEX, was incorporated to commercialize the technology, used both in anchors and piles. In 1993 the Expander Body was introduced into Bolivia by the company INCOTEC S.A. Until 2000, the projects with EB in Bolivia were constructed with the Swedish product. In 2000, thanks to an agreement between Bo Skogberg (SOILEX) and Mario Terceros H. (INCOTEC), a new design was developed. The main differences between the two products were the redesign to a round cross section instead of square cross section, watertight instead of allowing controlled leakages, digital register of volume and pressure instead of analogic registers, new type of connections with the shaft, and, finally, the post grouting system to further inject the soil below the expanded EB. Although the changes were made in Bolivia, the post grouting system was also adopted by SOILEX. During the R&D stage for the new EB version, 14 different designs were tested.

### 2.2. *Construction company*

#### 2.2.1. *INCOTEC S.A*

Incotec SA is the company that introduced the EB technology initially into the Bolivian market and subsequently to other countries in the region. Throughout its more than 25 years in the market, the EB technology captured a sizable percentage of the market from traditional systems due to its cost and time efficiency, technical reliability and versatility. The EB can be used with anchors or piles (including micropiles, underpinning, etc.), with different installation methods (drilled, driven, vibrated, pushed) and from open to very restricted areas. In 2015, the internationalization of the EB started with the creation of EBP (Expander Body Panama) to spin-off the EB from Incotec SA into an independent business branch.

#### 2.2.2. *EBP*

EBP Is the company created to commercialize the EB technology across the American continent. Contrary to Incotec SA (which is a contractor), EBP is a commercializing company. The business model works around finding allies in local markets and developing the business in each of the allies' designated regions. The first stage of market development in a new region is the technical promotion among experts, consulting companies, construction companies, universities and any other institution that is interested and can endorse the system. The second stage of market development consists in performing loading tests. Only seldom is it possible to find projects in which the tests are also part of the final construction. In general, the testing partners are specialized construction companies like HUB foundations (USA), EMBRE (Brazil), Logos (Paraguay) or ICP (Peru).

After endorsement and testing is in place, EBP starts selling EBs in the designated market through the local ally (commercial representative), providing permanent technical support without extra cost. EBP supports the involved stakeholders of a project from design to installation and QAQC of the system. In necessary cases, EBP also provides the training of the personnel for installation at the jobsite. This situation is less common as contractors are already experts in their fields.

#### 2.2.3. *EMBRE*

In the present case, the interaction between the companies was aimed to transfer knowledge of a new technology (EB) and its adaptation to the geological-geotechnical context concerning the tropical weathering profiles. Although widely applied outside Brazil, the technique was unknown to the Brazilian market, making it necessary and relevant to transfer knowledge between companies as well as their adaptation to the new geological-geotechnical reality.

It was necessary to present the conceptual framework to seek convincing in the theoretical and practical fields about the physical and engineering concepts incorporated in the EB, a fact that enabled the harmony of thoughts and actions, essential to provide knowledge and security about the technique when applied in this new geological-geotechnical context.

For technology transfer, companies' behavioral obstacles were first overcome, as companies had their own processes, techniques and ways of working. Technical convincing was achieved through technical forums, research and validation campaigns, for example, those conducted in the experimental field of the Graduate Program in Geotechnics at the University of Brasilia. The option for this study site was due to its geological and geotechnical peculiarities, which is very representative of the tropical weathering profiles.

With tangible and measurable results obtained in research and validation campaigns in relation to the profiles of tropical soils, results confirmed through campaigns to validate the profiles of the soils under study. Based on the results, the EB technique was validated for representative soils from tropical regions of Brazil. Important projects in the real estate market, in power transmission lines and in wind turbines were carried out in the Brazilian territory with the use of the technique. It should be noted that during the validation and research process, the processes necessary for the manufacture and installation of the EB were harmonized and improved, resulting in an industrialized product with a systematic installation process. This generated quality and commercial gains for companies involved.

The interaction between the companies were, therefore, positive, because in addition to promoting the technological improvement of the existing technology, it showed the consistency of its use in the building market and opened new frontiers of operation in the market focused on electric power transmission networks and for the installation of wind turbines.

#### 2.2.4. *Hub Foundation*

Hub Foundation is a Boston based company with which EBP started an agreement in 2015. Since then, several loading tests were performed in order to validate the system. So far, two important projects were built with EB piles. Hub Foundations organized the First EB Conference in 2018, in order to promote the system.

#### 2.2.5. *Advanced Foundations Solutions (AFS)*

AFS is a New York based company, incorporated in 2019 with the goal of promoting the EB in areas of the USA where HUB Foundation is not active.

#### 2.2.6.- *Expander Body Internationa (EBI)*

EBI is a Canada based company that in 2018 started promoting the technology not only commercially but also technically, performing loading tests and designs. They have performed loading tests for anchors, piles, micropiles for different uses, like docks, retaining walls, metro projects, high rise buildings, etc. EBP gives commercial and technical support.

### 2.3. *Instrumentation Company*

#### 2.3.1. *Ingertools*

Ingertools is a company in the field of control hardware and control software, focused on serving heavy industry. Because of the relationship between both companies, EBP asked them if they could have interest in developing a system for the EB injection control and in-field capacity determination of each injected EB. Due to the lack of budget, each company bought the necessary hardware. EBP bought the Flow Meter and Digital Pressure Transducers. Ingertools bought all the necessary electronics and assembled the system. The software was designed between both parties and Ingertools wrote the script. As the loading tests are a common tool in the projects, they also designed and built the hardware and software for execution and interpretation of loading tests, including their own resistive strain gages.

After the first project, Ingertools started the commercialization of those products plus some other minor ones to construction industry customers. Prior to this cooperation, Ingertools did not have any business in construction.

Before this cooperation, EBP only used conventional flow and pressure meters and the interpretation of the signals would have to be processed separately. With the current integration, all the processes are faster, more reliable, and facilitate decision making in the field. The price of the equipment developed with Ingertools is lower than the price of combining several commercial solutions to achieve the same goal.

### 2.4. *Engineering*

#### 2.4.1. *Soil investigations*

The quality of the soil investigation is perhaps the main value in the design and construction process. Although traditional investigation methods are still being used worldwide, the change to methods like Seismic Cone Penetration Test (SCPTu) and Seismic Dilatometer Test (SDMT) will be necessary to increase the quality of the information obtained during the soil investigation. INCOTEC SA has started to use these methods and the results show a direct benefit in reliability of the deep foundations, thus costs and time. Its experience has been very valuable for the soil investigations in projects with Expander Bodies.

#### 2.4.2. *Foundation's design and QA/QC*

Using adequate design methods for each construction technology is also a key question. Besides numerical methods (very dependent on the quality of the input information), the traditional design methods remain extremely general. During the constant development of the EB, pressuremetric methods and numerical models have been adjusted with high success. SRK, an international engineering company, also a ISSMGE Corporate Associate member, has been part of this process through their Argentinean office. They developed numerical models for the use of the Expander Body. As a result, both SRK and EBP improved their practices: SRK has new technologies to offer to their clients and EBP has higher quality tools enriching its know-how.

With INCOTEC, EBP is developing, a system to have the results of the EB injections available at the time of the ending of the injection, defining the resistance of each element and having all the data online, in order to take decisions without delay. This is a very valuable tool mainly in heterogenic soils where the behavior can vary significantly over short distances on the same site..

#### 2.4.3. *Equipment*

The design of the foundations should include the construction technology. Different research shows the importance and effect of the construction technology in the final results. The cost and time implications are significant and the combination of any method with the EB system is also important to take in account. Since 2012 INCOTEC SA has worked with BAUER equipment. They have generated a close relationship not only in the commercial aspects but mainly in the technical collaboration. BAUER became an important support for the projects in which INCOTEC SA started with new construction methods, giving the feedback to BAUER. Several of the new technologies improved the use of the Expander Body. The knowledge acquired is shared with other stakeholders of EBP.

## 3 CONCLUSIONS AND RECOMMENDATIONS

The positive experiences show, at least, the following conclusions:

-It is possible and practical to establish an efficient collaboration/cooperation among companies of the geotechnical business, not only in complementary fields but also between companies that are apparently competitors. The key question is to understand the benefits of complementation.

-It is economically beneficial to have a network of cooperation

-The size of the companies could be very different for the cooperation.

-The technical cooperation, based in the criteria of Open Innovation, could create not only new technologies but also new markets.

-The cooperation results will always be more valuable than the individual sum of the parts.

-In a cooperation process, a lot of time and resources are saved because one participant may already have developed the topic. This shortens the necessary time to adopt new technologies or to start new markets.

-The model can be adapted to other fields in the companies, like commercial and marketing of new technologies.

As recommendations we can mention:

-Having an open discussion among CAS (ISSMGE CORPORATE ASSOCIATES) members to identify potential interest of cooperation.

-Define new lines of cooperation

-Promote the Open Innovation concept also outside the CAS group

-Periodically share the experiences with CAS members

-Update of standards after successful cases of implementation of new technologies.

-Generate publications to promote the cooperation method in order, also, to facilitate the access of low technology companies to the market

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