Impactos das Tecnologias nas Engenharias 5

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APRESENTAÇÃO

Caro leitor(a)

A engenharia, em um aspecto etimológico é derivada do latim ingenium , cujo significado é "inteligência" e ingeniare , que significa "inventar, conceber". A inteligência de conceber define o engenheiro.

Fácil perceber que aqueles cujo oficio está associado a inteligência de conceber, dependem umbilicalmente da tecnologia. Mostrar parte desta ligação é o principal proposito desta obra.

Nela reunimos várias contribuições de trabalhos, ligados sobretudo a indústria petroquímica com potencial de impacto nas engenharias. São apresentados vários trabalhos de cunho tecnológico associados a temas como Biodiesel, Offshore, técnicas e ensaios associados a manutenção e segurança, processos químicos, entre outras temáticas. Todos com resultados e discussões enriquecedoras.

Aos autores dos diversos trabalhos que compõe esta obra, expressamos o nosso agradecimento pela submissão de suas pesquisas junto a Editora Atena. Aos leitores, desejamos que esta obra possa colaborar com suas carreiras e gerar uma reflexão mais aprofundada sobre a relação entre a tecnologia e a engenharia.

Boa leitura!

Franciele Bonatto
João Dallamuta
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SUMÁRIO

CAPÍTULO 16

CONCEPTUAL DEVELOPMENT OF AN UNDERGROUND EXCAVATION TECHNIQUE

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ABSTRACT: Population growth has generated increasing demands for infrastructure and the need to explore underground space allowing the development of modern society. However, in developing countries, underground infrastructure is still relatively precarious and the method commonly used to perform microtunnels in soils relies on manual excavations. Nevertheless, if not properly executed, these works can present several problems and even cause collapses during its execution. On the other hand the mechanized equipment is extremely costly. This scenario presents a favorable environment for innovation in which can take place through the introduction of a degree of mechanization into the manual excavation technique, providing safety and reduction in execution time in a simplified way and with low costs, presenting to society an appropriate technique to the developing countries reality. The present work adopted a product development method known as PRODIP to achieve a new technique for microtunnelling in soil. This new technique employs traction cables attached to a shield and a slab, enabling a rational solution for its advancement and eliminating the need of high-strength lining. Therefore, as a result, the paper presents an innovative approach to the executive process of microtunnels through a semi-mechanized excavation equipment, with advantageous characteristics regarding to the tunnel shape, the advance system, the safety and the overall quality of the work.

KEYWORDS: Underground Infrastructure, Soil Excavation, Tunnel Engineering

1 I INTRODUCTION

For hundreds of thousands of years the population has been restricted to the use and exploration of the two-dimensional space of the earth's surface. However, with the population growth there was a need to explore the third dimension not only with the verticalization of the buildings but also with tunnel construction for transportation and utilitarian services. The use of underground space has become fundamental in the execution of infrastructures that allow the development of modern society. Currently, a wide variety of underground structures are used to improve people's quality of life, both in and out of large cities (STERLING, 2002; GODARD, 2002; TENDER, 2017). However, according to Broere (2016), in developing countries, infrastructure is relatively precarious, causing problems such as large vehicle congestion, high noise and pollution, floods, among others (BROERE, 2016).

Despite substantial progress in knowledge and technologies for construction of underground infrastructure the costs are still considered to be higher compared to surface buildings. The difference in costs is even more significant when involves mechanized construction method that requires highly trained professionals (GODARD, 2004). This fact makes several small and medium-sized enterprises, in developing countries, opt for the manual excavation method. As this method is heavily dependent on empirical knowledge and possible soil treatments to ensure safety, a number of construction problems can occur.

The mechanized equipment more used in soil excavation for microtunnels are pipe jacking (PJ) and horizontal direction drilling (HDD). Both technologies require lining with high strength due to the constructive process. On the one hand, in PJ construction the lining is pushed while on the other hand in HDD process the lining is pulled (SENDA, 2013; ZAYED, 2013).

Based on problems that may occur using manual techniques in addition to high acquisition cost of mechanized equipment, it is necessary to develop a low cost solution that guarantees the minimum of safety and introduces techniques that increase productivity. This could have a positive impact on the safety and technical quality of the works.

The innovation comes with the introduction of a degree of mechanization into the manual excavation technique. In this sense, the article presents the concept of microtunnel excavation equipment specially focused on small and medium-sized enterprises, aiming to meet the demand of the national market, promoting an original technology, with high security and competitive cost.

2 I DEVELOPMENT PROCESS: NEW SPECIFICATIONS AND OPERATIONAL CYCLE

The development process used was based on a systematic method called PRODIP which was elaborated by the Product Development Laboratory of the Santa Catarina Federal University (NEDIP). The model is divided into three macrophases: planning, design and execution. However the focus will be given in the phases of informational and conceptual design, as shown in Figure 1 (BACK et. al, 2008).

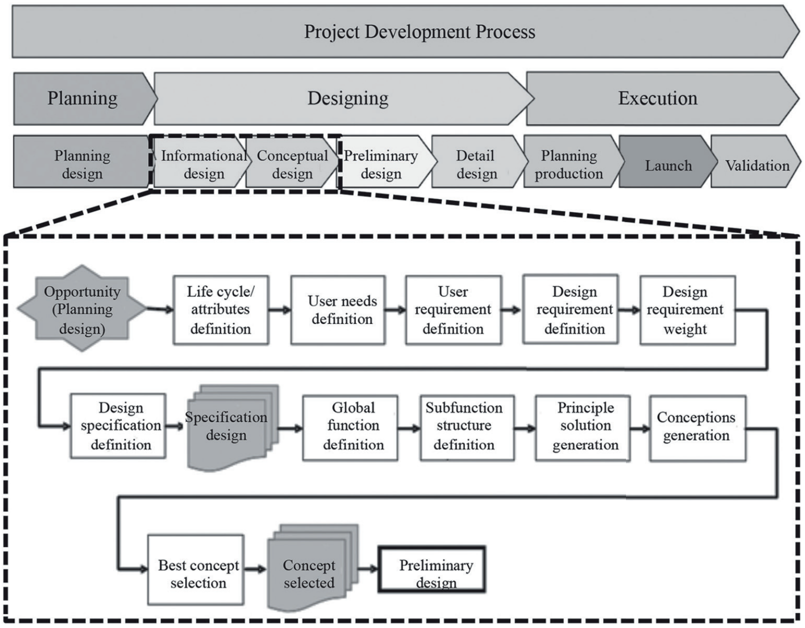

Figure 1 - Project development process based on PRODIP method.

Source: Santos, 2018

The informational design begins with the definition of the life cycle and follows all steps until the definition of the specification design. Therefore, the first step is to define the life cycle that describes all the steps by which the product must go from ordering the equipment to operation and storage. From the definition of the life cycle it is possible to define the stakeholders involved. With this is possible to establish the user needs that are transformed into user requirements and are translated into design requirements that are nothing more than assigning measurable characteristics. Finally, after ordering the degree of importance that must be met in the design requirements, the specifications design have been established, as shown in Table 1 (BACK et al, 2008; FONSECA, 2000).

Description	**Inquiry mode**	**Acceptance criteria**	**Classification**
Environment and safety standard	Inspection	NR04-06, 09, 11, 12, 15-17, 22, 23	Required
Cost per meter executed	Cost analysis	Less than US$ 17 thousand/m	Required
Acquisition cost	Cost analysis	Less than US$ 10 thousand/m^2	Required
Advanced rate	Operational record	More than 5 m/day	Required
Operation rate	Operational record	More than 80%	Required
Deviation of path	Topography	Less than 0,5%	Required
Deviation of section	Topography	Less than 5 cm	Required
Recycling rate	Inspection	More than 50%	Desirable
Automatic control	Manual user	More than 50%	Desirable
Components dimensions	Dimensional measurement	Less than 3 m	Required

Components weigth	Weight measurement	Less than 2000 kg	Desirable

Table 1 - Specification design classified by the importance in the group. The acceptance criteria and inquiry mode can be found as well.

After obtaining the specifications design, the conceptual design starts from the global function definition following all the steps until the selection of the most appropriate concept. Thus, the first step was to define the main inputs and outputs of the excavation process. With this is possible to obtain a global function that is a base for the sub function structure definition, as showed on Figure 2.

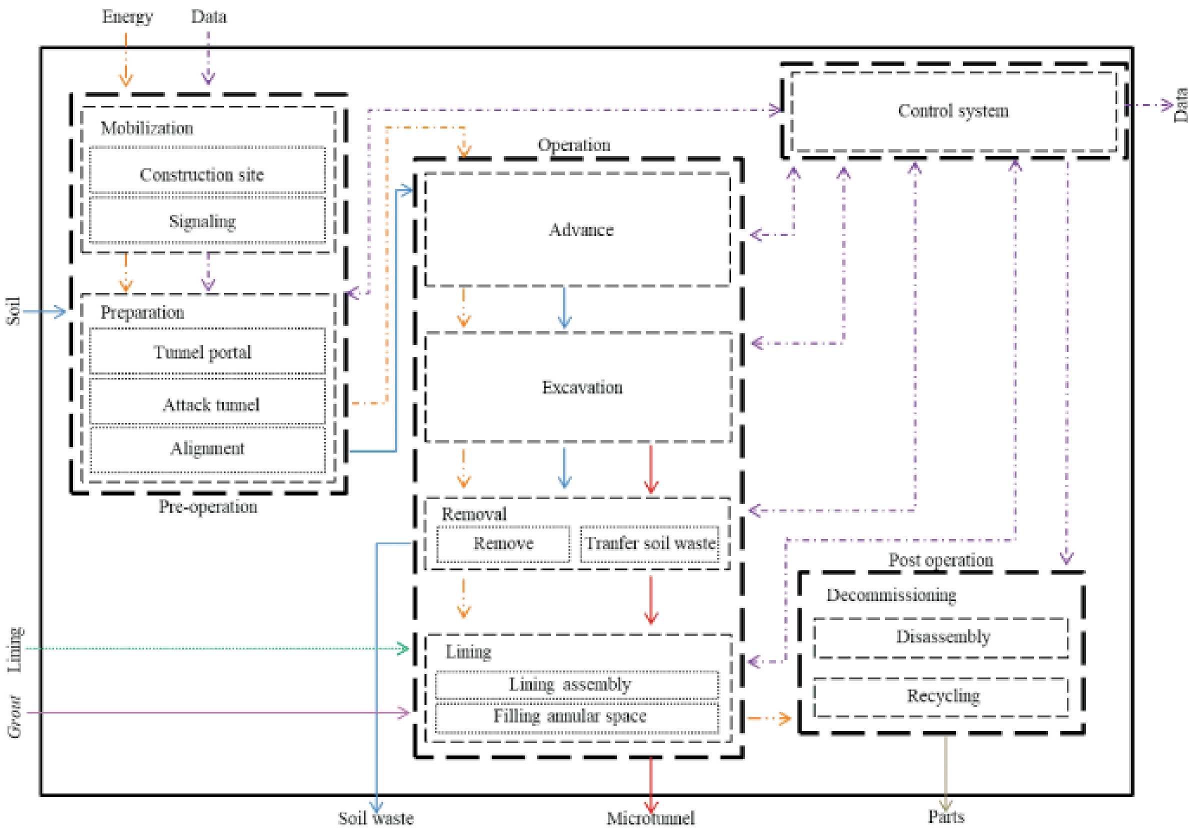

Figure 2 - Subfunction structure and relationship between the mains inputs and outputs.

The subfunction structure is divided into 4 steps: Pre-operation, Operation, Post-operation and Control system that updates the input and output data during all the process. The pre-operation stages consist of the activities of mobilization and signaling of the construction site and a preparation where the activities are carried out for the proper alignment of the equipment. The operation phase is a cyclic activity that begins with advancing, soil excavation, removing and transporting waste, lining assembly and filling the annular space until the microtunnel is finished. Finally, the equipment is decommissioned with the disassembly and recycling of its components. Essentially, each subfuntions have to bring solutions which must be organized into a matrix denominated morphologic matrix. The combination of these solutions generate the conceptions that are considered in the selection process. In total were obtained

Seventy two conceptions that were evaluated and the ones considered to be more adequate will be presented.

3 I EQUIPMENT CONCEPT AND OPERATIONAL CYCLE PROPOSED

3.1 Equipment concept proposed

The conceptual development proposed by Back et al. (2008) allowed to define a preliminary layout of the excavation equipment composed of a shield and a metal plate connected through steel cables as showed in Figure 3.

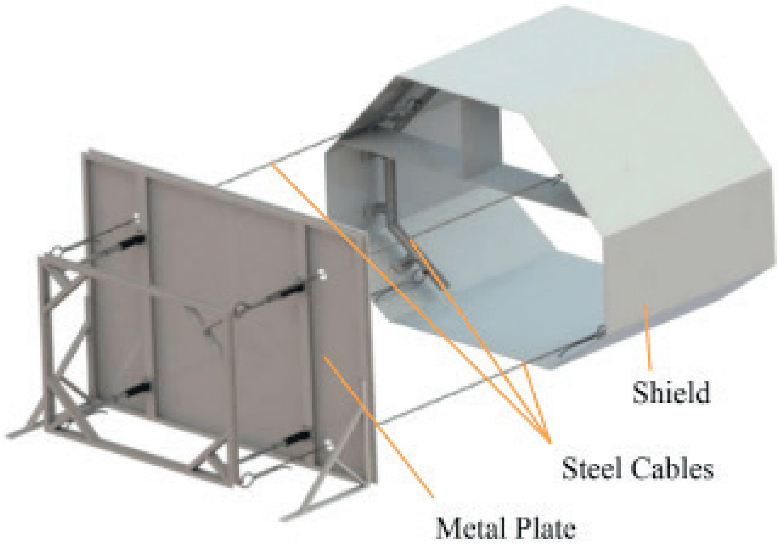

Figure 3 – Equipment concept propos

The shield has the function of providing the temporary support during the process of soil embed and excavation. The shield shape must approach the contour of the lining causing reduction of the amount of filling material, as can be seen in Figure 4. In this case was used the lenticular shape but it can vary to attend the need in others situations.

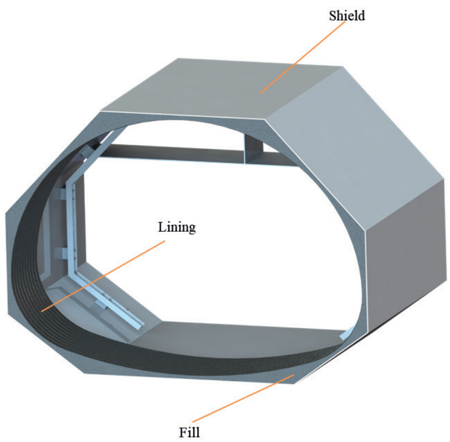

Figure 4 – Shape contour of the shield.

Another point that draws attention is the presence of grid in the frontal region that has the function of protecting the front of a possible destabilization of the ground and avoiding that a great amount of material overruns its interior, as presented in Figure 5.

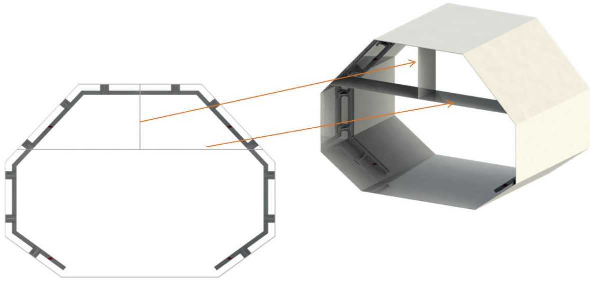

Figure 5 – Grid in the frontal region of the shield.

Inside the shield there are metal beams that play the role of providing greater strength and stiffness to the shield. In addition, there are, on the beams, lifting lugs which the steel cables will be allocated and will make the union between the shield and the metal plate. The connection between two beams can be made by screws and bolts similarly the connection between beam and the support. On the other hand, the support is welded on the shield to ensure the safety of the system, as illustrates in detail in Figure 6.

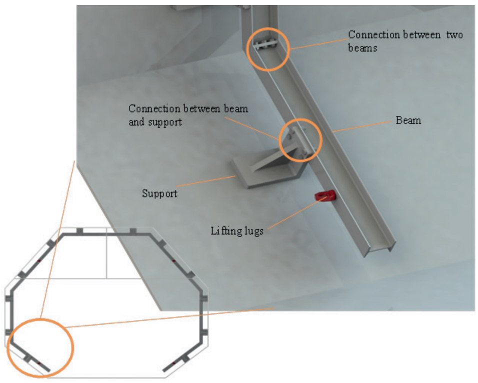

Figure 6 – Details of the connections inside of the shield.

The metal plate is formed by a steel plate reinforced by metal beams and a movable plate formed by other beams besides two supports to avoid the tipping of the plate. The metal plate contains holes for the passage of the steel cables that will be allocated in the lifting lug arranged in the movable plate, as presented in Figure 7.

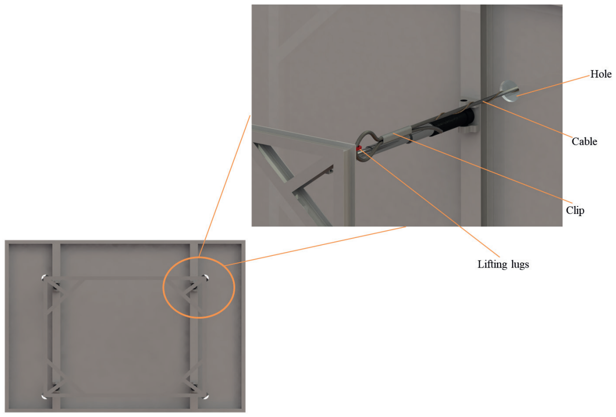

Figure 7 – Metal plate details.

Finally, there are cylinders that are placed on fixed metal plate that will be responsible for the displacement of the movable plate, as showed in Figure 8. While movable metal place initiate its movement the cables starts to stretch and consequently will cause shield movement.

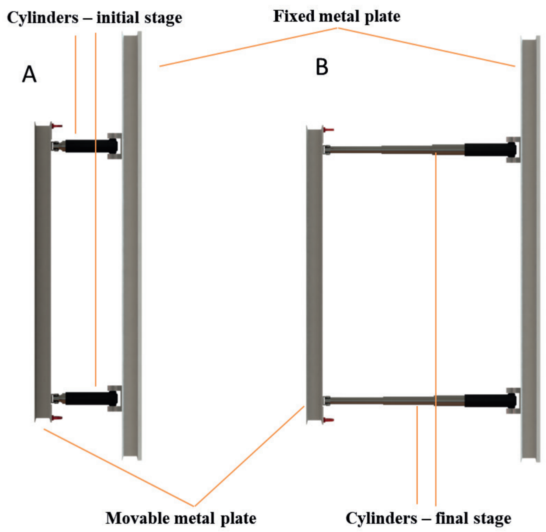

Figure 8 - Initial stage (A) and final stage (B) of the cylinders.

3.2. Operational cycle proposed

After preliminary layout defined, it is possible to establish the executive procedure of the entire process. There are several steps that initiate with the implantation and signaling of the construction site that is based on regulatory standard NR18. According to the NR18 standard, the work area must be previously cleaned removing rocks, materials and objects of any nature or when there is a risk of compromising its stability during the services. The second step concern to make the tunnel portal which has the function of defining the excavation area and planning the soil so that it is possible to start the alignment activity, as illustrated in Figure 9.

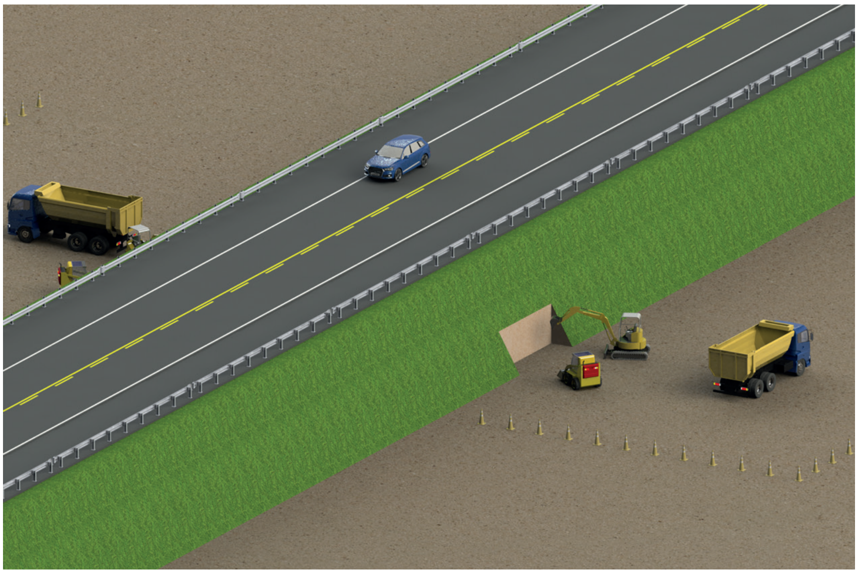

Figure 9 – Tunnel portal construction.

The next step is drilling the soil that will cross the ground to pass the cables (Figure 10). However, to avoid the closure of the ground a guide pipe, which may be of steel or other material, is installed and its inside will be placed the steel cables. Also to avoid serious accidents in the event of the rupture of the steel cable a safety cable is required which envelops it over its entire length.

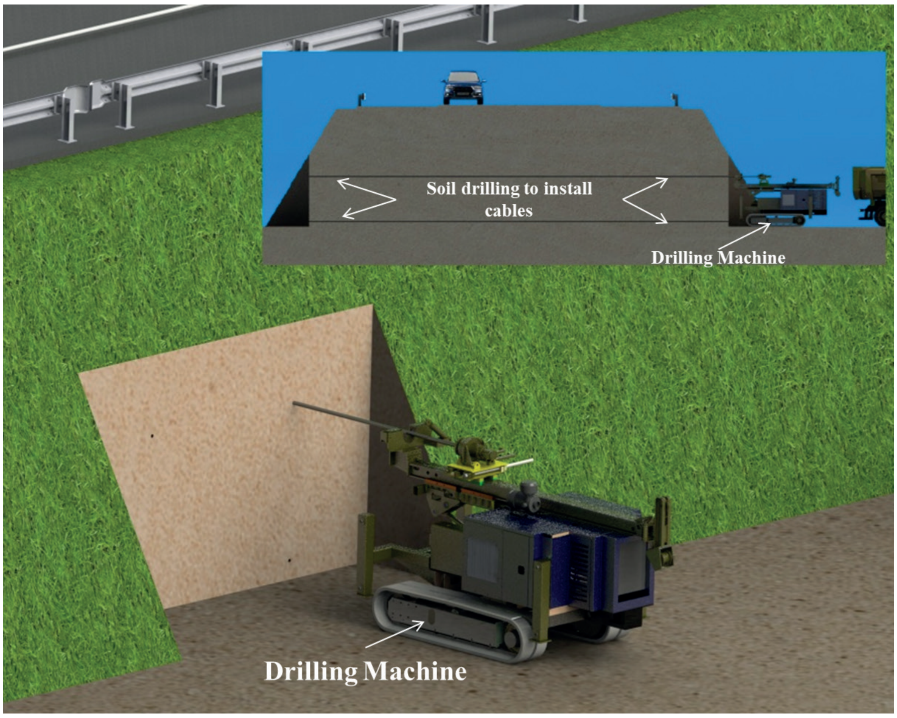

Figure 10 – Soil drilling to install the steel cables.

The further action will be to position and connect the shield with the metal plate and then a cyclical operation has initiated. All begins with the expansion of the cylinders, giving rise to the movement of the shield until it is embedded to the ground, as can be observed in the Figure 11.

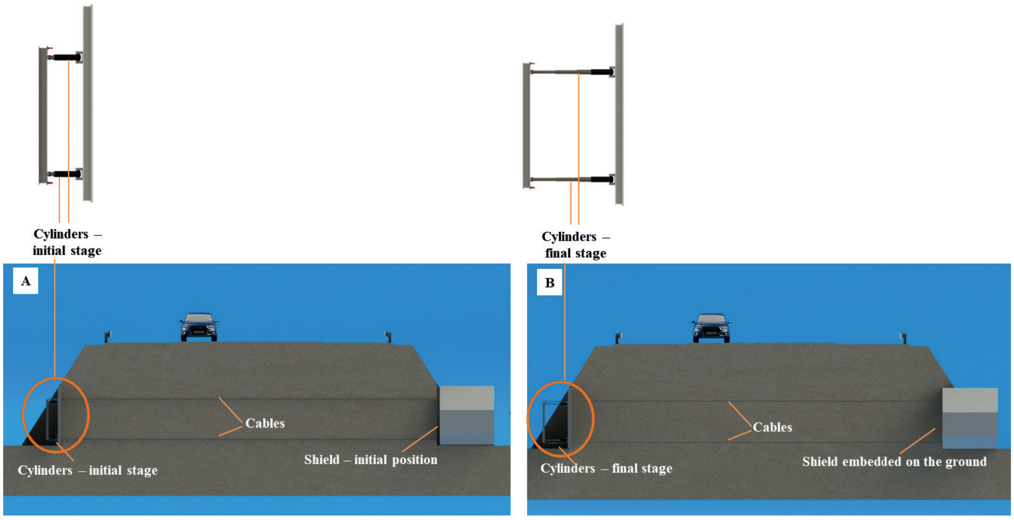

Figure 11 – Shield embebbed to the ground with the cylinders motion.

The next step concerns soil excavation, which can be performed mechanically or manually or both (Figure 12 A). As the shield advances, the permanent lining is assenbled and voids are filled (Figure 12 B). Besides, the excavated soil must be removed and this can occur by wagons that slide on rails that will be mounted at the base of the tunnel to facilitate their locomotion (Figure 12 C).

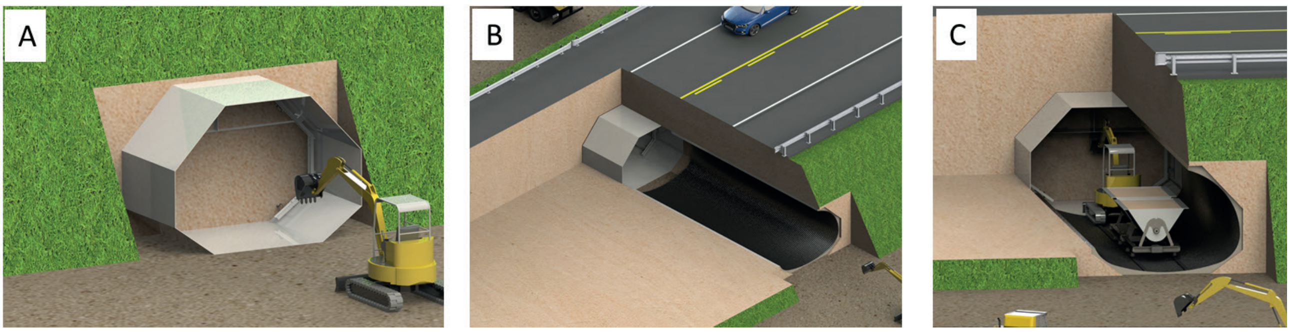

Figure 12 – A: Soil excavation; B: Linning installation; C: Residual soil remotion.

This cycle will be repeated until the microtunnel is totally finished. The last step is the equipment decommissioning that consists of the shield removal from the ground and the disassembly of all devices. Some of these must be recycled or used in another work and some can be discarded. Finally with the complementary services the new infrastructure is ready to be used, as Figure 13.

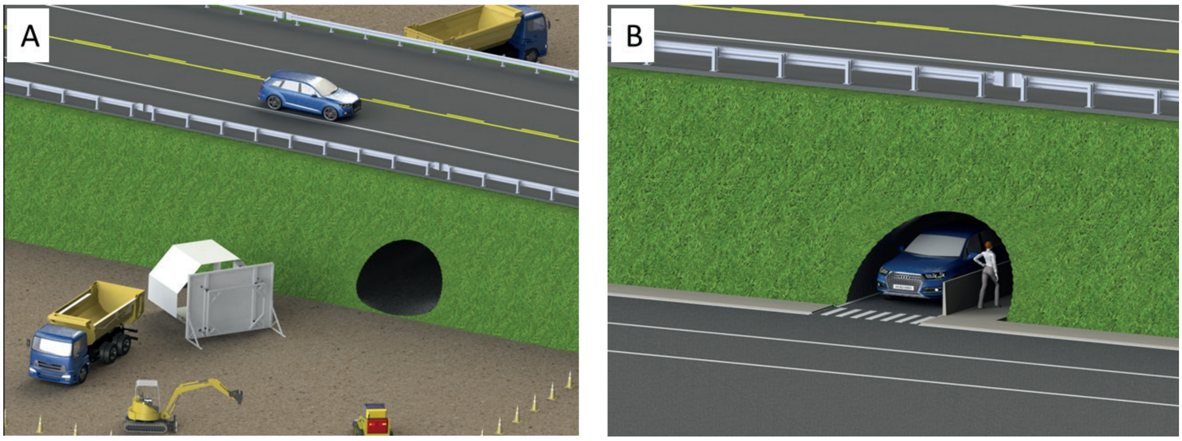

Figure 13 – Final services (A) and microtunnel delivery to society (B).

4 I FINAL CONSIDERATIONS

The development design based on PRODIP method led to the concept of equipment for soil excavation in straight and short part. The study provided a degree of mechanization in manual excavation with the addition of an innovative cable trapping system that moves the equipment without requiring lining efforts with great importance to the infrastructure demands of the Brazilian society.

In future works will be presented the ground repression due to the construction process, the costs and the execution schedule that will provide the validation of the design.

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