Sustainable development of infrastructures using underground spaces: role of academia

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Abstract

This paper presents how placing infrastructures under the ground can improve living conditions and minimize environmental impacts. Status of tunneling education in the USA has been investigated and compared with the industrial needs. Adjustments to the current Civil Engineering programs have been proposed. Furthermore, a curriculum has been suggested for a MS program in Tunnel Engineering. Finally, the paper briefly presents some examples that academic research can improve design and construction approaches for underground spaces.

Introduction

United Nation Center for Human Settlements (UNCH)-Habitat[1] indicates that the ratio of urban to total world population increased from 10 to 60% between 1950 and 2000 with a rate of 60 million per year. In 2015, 10% of people are expected to live in 26 mega-cities. These statistics reveal the importance of investment in urban infrastructures, which emphasize mobility and storage.

Considering the land area of the earth (150×10^6 km^2) and an annual population growth rate of 1.68%, one may expect that 650 years from now, there will be only one square meter per person. Thus, to improve living conditions and minimize environmental impacts, it would be prudent to use the underground space for infrastructure, leaving the surface for more noble needs. On the other hand, United Nation Economic and Social Council[2] would like to place infrastructures underground to enhance food production, improve income opportunities for the rural poor, and improve sanitation and water quality. In addition, by placing infrastructures underground, future generations can use the aboveground. Thus, underground infrastructure is a sustainable development, which is defined as a development that meets the needs of the present generation without compromising the ability of future generation to meet their needs.

Underground solutions can solve many urban problems in different areas, such as transportation (mass transit, urban motorways, and railway links), public utilities (water supply, sewage, and cables), city center revitalization, and storage (car parking, flood control, and goods storage). The following examples effectively show the scale of underground infrastructures being (or to be) constructed in the world: In Europe, the Lyons-Turin link tunnel is a 200-km-long infrastructure (Figure 1). Inauguration of the base tunnel is scheduled for 2020 with a budget of several billion Euros. In Singapore, the Deep Tunnel Sewerage System (DTSS) project consists of two large tunnels with a total length of 80 km and 170 km (Figure 2). In the city of Austin, Texas, 33 km water/sewage tunnel projects are under planning, design, and construction. In the USA, tunneling business has annual revenue of about 17 billion dollars per year (2 billion dollars per year just in New York City).

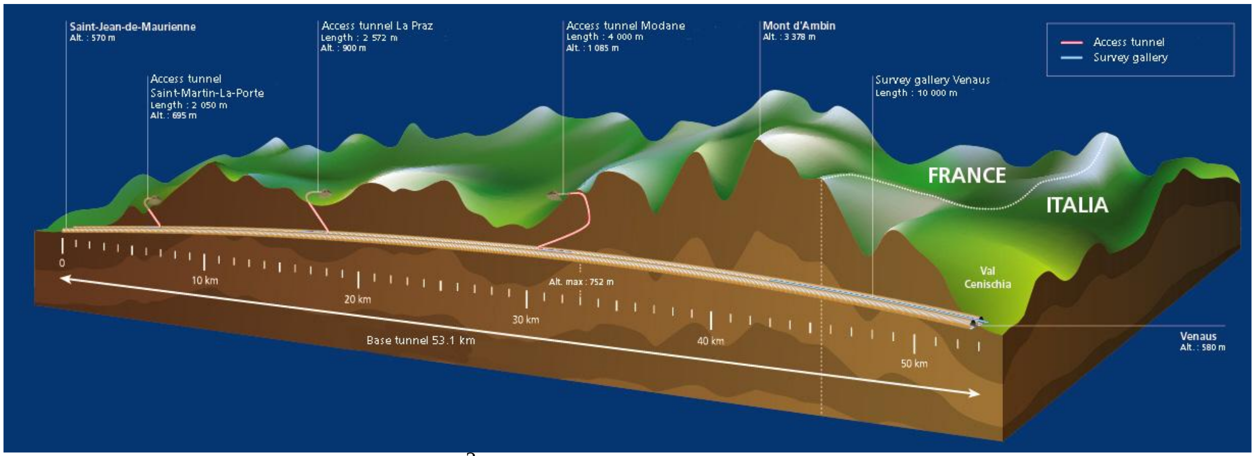

Figure 1: Lyons-Turin Link Tunnel[3]

Figure 2: Deep Tunnel Sewerage System (DTSS) project[4]

Consequently, the underground spaces can be considered as a sustainable solution for infrastructures. This paper deals with the role of academia in preparing Civil Engineers with expertise in tunneling and underground excavation. Section 2 summarizes the status of tunneling education in the USA. Possible contributions of academia to the civil engineering professional society through both teaching and research are investigated in Sections 3 and 4, respectively.

Current Status of Tunneling Education in the USA

Considering the difficulties of developing an educational program devoted to tunneling, it is not unexpected to have few schools with such capabilities. Probably the most successful program for tunneling existed at the University of Illinois at Urbana-Champaign beginning in the early 1970s and continuing until the late 1980s. The earmarks of that program consisted of the following: strong dedicated faculties, funding, and interaction with tunnel construction industry[5].

Regardless of the history of tunneling education (teaching and research) at different schools, here are the names of US universities which have active faculties with expertise in tunneling and underground excavation: the University of Illinois at Urbana-Champaign, Massachusetts Institute of Technology, Colorado School of Mines, Louisiana Tech University, Cornell University, the University of Texas at Austin, Pennsylvania State University, Idaho State University, New Jersey Institute of Technology, and the University of the District of Columbia.

Very few tunneling courses are offered at US universities, and therefore it is very likely that a civil engineer is not exposed to tunneling in his formal education. On the other hand, industry demand for tunnel engineers is extremely high and even increasing.

Undergraduate and Graduate Tunneling Courses

The basic traditional idea is to adjust current undergraduate and graduate Civil Engineering curricula to prepare student for tunneling projects. To reach this goal, one undergraduate senior course entitled "Tunneling: Design and Construction" can be developed. Moreover, two graduate courses can be offered in geotechnical engineering programs: "Rock Engineering" and "Designing Tunnels Using Numerical and Analytical Methods".

The ideal situation is to have a professional MS degree in Tunnel Engineering. The core courses of this program are as follows: "Introduction to Tunneling", "Engineering Geology", "Rock Engineering", "Advanced Soil Mechanics and Geotechnical Engineering", "Site Investigations (Rock and Soil)", "Analytical and Numerical Methods", "Excavation in Rock", "Mechanized Tunneling", "Monitoring and Surveying", and "Risk Assessment and Management".

Academic Research in Tunneling

Academia can perform different valuable studies on underground urban infrastructure. For example, in urban areas, mostly with very low overburden and high water levels, the excavation method has always been an issue. Several generations of NATM (New Austrian Tunneling Method) consultants have us believe that NATM necessarily uses the Sequential Excavation (SE) method. However, Rabcewicz (the developer of NATM) said "tunnels should be driven full face whenever possible." ADECO (Analysis of Controlled Deformations in Tunnels) allows us to fulfill this dream in any stress-strain conditions[6]. The questions are which one is safer (SE or ADECO) and which one costs less.

In addition, the development of underground infrastructure requires multidisciplinary research. For example, although statistics show that the fatality risk in tunnels is generally lower per vehicle km than it is for a comparable open infrastructure, some specific events are unique for tunnels and can lead to much more severe consequences than they would in an open section. Thus, for tunnels, it is of major importance to address these issues. Examples are explosions, release of toxic gases and other dangerous substances, and flooding in tunnels, which are below the water level. In the past, assessment of road tunnel safety was based on experience and prescriptive guidelines. Updating some of these codes has included developing a methodology for an integrated quantitative risk analysis. Initially, the main objective is to establish a risk-based decision tool, which specifies important safety requirements of road tunnels (e.g. ventilation systems). Although insightful studies have been performed which analyze the foremost discussion of tunnel specific risks (fires in tunnels), the analysis methods are not very well developed yet. In addition, risk analyses of other events remain almost intact.

Summary

It is believed that to improve living conditions and minimize environmental impacts, infrastructures can be placed under the ground. In addition, our investigation reveals that current status of tunneling education in the USA does not satisfy the industrial needs. Therefore, adjustments to the current Civil Engineering programs have been proposed. However, it is believed that new MS program should be developed for Tunnel Engineering. Finally, some examples of research ideas dealing with underground excavation have been given.

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