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Smart system for safe and optimal soil investigation in urban areas

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Abstract

This paper discusses the challenges and difficulties experienced during soil investigation in urban areas using drilling machines and soil sampling. The focus is on the consequences of a lack of data on the subsoil profile and presence of utilities, which could cause major accidents with severe economic and social losses, resulting in constriction activities being delayed and urban services being disrupted. This paper describes certain accidents related to soil investigation in Qatar and their consequences, as well as the lessons learned from these accidents. In order to meet the challenges of soil investigation in urban areas, this paper presents a solution based on smart technology, which includes: (i) a geotechnical information system with update data concerning the soil profile, soil surface, utilities locations, and water table level; (ii) tools for data management, analysis, and visualization; and (iii) a user interface that allows authorities, companies, and citizens to access authorized data via a graphic interface, update data, and send messages and alerts in the case of any incident occurring. Finally, the paper presents a promising perspective for the development of smart drilling devices, which record data related to the functioning of a drilling machine and transmit data to the smart soil investigation system.

Keywords: Soil investigation; Smart; Urban area; Drill borehole; GIS; Underground utility

Introduction

Arabian Gulf countries are experiencing rapid urban development, with intense construction activities taking place to meet the need for economic and social development as well as large anticipated events such as the Expo 2020 in Dubai and FIFA World cup 2022 in Qatar. These circumstances require intense workability and productivity in order to achieve public and private sector targets. Consequently, certain areas are simultaneously subjected to different construction projects at various progress phases, varying from the design and primary construction phases to the final construction phase. As construction activity is intense and carried out at an extremely rapid rate, certain major difficulties are encountered in the coordination among authorities and companies, as well as in updating the data concerning urban infrastructure construction and extension.

In certain areas, recent changes in infrastructure have not been reported in plans shared by companies and public authorities, and soil investigation may consequently cause major accidents by damaging utilities such as sewage networks, water networks, the electrical grid, and telephone lines. This damage may lead to a disruption in the supply of urban services such as water, energy, telecommunications, and transport, with heavy economic and social losses, as well as Resulting in significant delays in construction activities.

This paper describes certain accidents that occurred during soil investigation in Qatar, Doha, and their consequences, as well as the lessons learned from these

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accidents. It demonstrates that the accidents occurred owing to a lack of update information on the subsoil or misunderstanding of the soil profile. Furthermore, it is demonstrated that a large delay in mitigation measurement largely exacerbates the consequences of these accidents.

The recent development and use of smart technology in urban areas (Anthopoulos & Fitsilis, 2013; Bhalla, Yang, Zhao, & Soh, 2005; Chai et al., 2011; Lin, Li, Fan, & Gao 2013; Self, Entwisle & Northmore, 2012; El-Hawary, 2014; Jiang, Lin, Qiang, & Fan, 2015; Rao & Chandran, 2013; Shahrour et al., 2016) presents an excellent opportunity to use this technology for improving the safety and efficiency of soil investigation in urban areas, as well as to improve coordination among companies and authorities and reduce operational costs (Annaswamy, Malekpour, & Baros, 2016; Balakrishna, 2012; El-Diraby & Rasic, 2004; Weiss, 2009).

This paper presents the architecture of a smart system that allows for improving the safety and efficiency of soil exploration in urban areas. The system includes a geotechnical information system with update data concerning the soil profile and utilities, tools for data management, analysis, and visualization and a user friendly interface that allows authorities, companies, and citizens to access authorized data, update data, and send messages and alerts in the case of the occurrence of any incident. Furthermore, the paper presents a promising perspective for the development of smart drilling devices, which record data related to drilling operations and transmit data to the smart soil investigation system.

Soil investigation challenges in urban areas

Soil investigation in urban area encounters major difficulties as a result of limited access to the soil investigation area, noise limitations, soil heterogeneity, and the presence of various objects in the subsoil, such as utilities, cavities, blocs, which are not always known or indicated in documents and maps. The absence of data concerning urban soil could lead to severe accidents such as utilities damage, which may result in serious economic and social losses, and disturbances to urban services, such as traffic as well as water and energy supply.

Furthermore, in certain countries that do not apply centralized management of urban utilities, any soil investigation campaign requires permits from different authorities, such as electrical, gas, drinking water, sewage, telephone, internet, pavement, and metro authorities. These permits take a long time to be granted, which could lead to significant delays in the soil investigation campaign.

The investigation of underground construction in rapidly developing areas also raises specific challenges. In soil investigation for metro projects, although the main metro lines and stations are well known, the connections between the metro and public networks are not always effectively indicated because of their complexity, intense construction activity, the high number of contractors and sub-contractors involved, great depth of certain utilities, and use of various backfill materials.

Safety should be determined before embarking on any geotechnical exploration in urban areas, in particular to ensure the absence of utilities in the investigated area. Methods used to determine the presence of utilities are mainly based on manual excavation to a certain depth. If any utilities are found, manual excavation of the utility pit must completed in new location. This procedure requires a long operating time, with associated high costs. Cable detectors are used to check for the presence of cables down to a certain depth.

According to certain standards (BS5930; EN 1997-2), boreholes should be preceded by A hand excavation inspection in order to ensure the absence of any underground utilities. This procedure should be carried out until a safe depth is reached to begin drilling. This process is generally undertaken followed by soil investigation teams, but in certain cases, accidents resulting in damage to utilities may occur. The following situations may lead to utilities damage: (i) soil investigation in areas incorporating utilities at large depths, where utilities are not indicated in the existing plans or at the ground surface; and (ii) soil investigation in areas with backfill materials, which cannot be distinguished from the existing soil.

Examples of soil investigations causing utilities damage

This section describes three soil investigations carried out in Qatar that caused utilities damage.

Damage to sewage pipes

The first example concerns a site where the available geology data indicated the presence of rock bed at a depth of 1 m, which was confirmed by the standard inspection pits at the borehole location. Following this confirmation, drilling operation was carried out; however, at a depth of 6 m, sewage pipes were encountered and damaged by the drilling machine. Fig. 1 illustrates the borehole location and damage consequences. In this case, damage occurred despite all precautions being taken. The procedure for stopping the sewage flow required approximately eight hours. During this time, the damage increased, causing erosion and collapse of adjacent roads (Fig. 2), as well as soil pollution. The road was closed for three days in order to carry out utility and road reparations. The delay in stopping the sewage significantly amplified the accident impact.

The investigation into the reason for this accident occurring indicated that rockfill materials were used in this area. These covered the sewage pipelines, and were not reported in existing plans or at the ground surface. Furthermore, the geological map indicated the presence of a rock layer at a depth of 1 m, which was unfortunately observed only during manual excavation.