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Editorial

Risk Management Technologies for Deep Excavations in Water-Rich Areas

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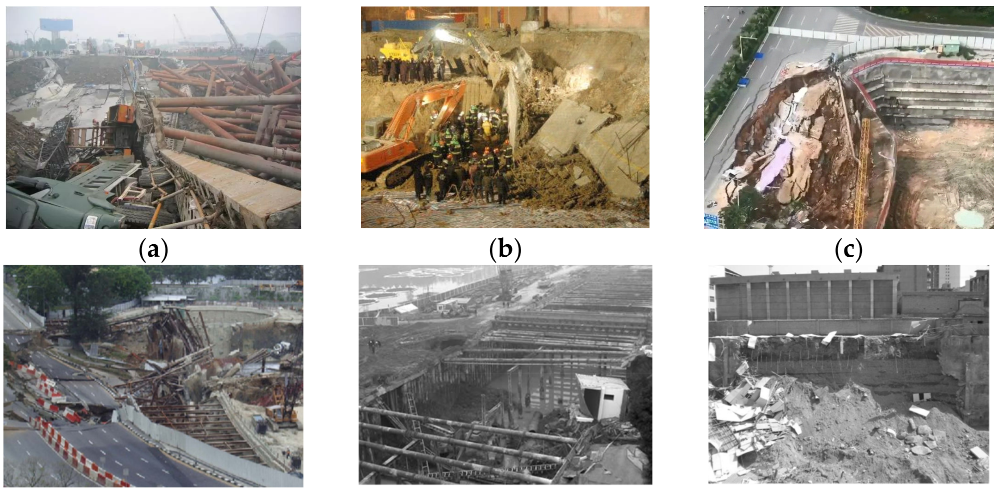
1. Introduction

Deep excavations play an important role in the construction of urban infrastructures such as metro stations and high-rise buildings [1–3]. In recent decades, the depth and plan view size of most of the deep excavations in megalopolises are becoming unprecedented, due to growing usage requirements [4–7]. For example, the depth of the deepest excavation for a metro station in China, the Binjiang Station of Nanjing Metro Line 2, reached 51 m. Such a large excavation depth will inevitably bring challenges in controlling the safety and stability of the excavating work and its surroundings [8–10]. Moreover, the geological and hydrological conditions faced by deep excavations are increasingly complicated. Soft soils and high groundwater levels are not uncommon in deep excavation [11–13]. Therefore, the safety risk of deep excavations remains high, and various types of deep-excavation-related accidents have occurred in many parts of the world, causing enormous economic losses and casualties [14–18]. Figure 1 shows photos of typical cases of deep-excavation-related accidents [19].



(a) (b) (c) (d) (e) (f)

Figure 1. Photos of typical cases of deep-excavation-related accidents in many regions: (**a**) Hangzhou; (**b**) Harbin; (**c**) Nanning; (**d**) Singapore; (**e**) Wuhan; (**f**) Xining (after Guo [19]).

In water-rich areas, most deep excavations are affected by groundwater. During the construction of deep excavations in water-rich areas, for the sake of preventing seepage failure, effective dewatering measures have to be taken [20,21]. These measures provide a dry construction environment, which is beneficial for the stabilization of the excavation slope. However, dewatering can be detrimental in that it induces considerable and differential ground settlements, complicating the stress and seepage fields surrounding the site. On the one hand, dewatering can increase the effective stress in the soil skeleton surrounding the deep excavation, which induces ground settlement [22,23]. On the other hand, the dynamic water pressure generated by dewatering-induced waterhead difference will further exacerbate ground settlement [24,25]. Excessive and differential ground settlements can induce cracking, structure tilts, pipeline fractures, and other disasters in buildings. Additionally, the coupling of the seepage field and stress field during dewatering is rather complicated. Thus far, its mechanism and effect on the stability and deformation behavior of the deep excavation have not been well understood [26–28]. Thus, the safety risk of deep excavations in water-rich areas is extremely severe compared to that in arid areas.

The safety risk of deep excavations in water-rich areas has aroused extensive research interest among geotechnical engineers and researchers worldwide. Since the pioneering work of Einstein [29], who introduced the risk management concept to the field of underground engineering, significant advances have been made in risk management technologies for deep excavations. In detail, risk management technologies contain three critical aspects: risk identification, risk assessment, and risk control. Obviously, this is the primary step in identifying the various risk factors for ensuring the safety of deep excavations in water-rich areas. On this basis, risk assessment needs to be performed to ascertain the risk grade and the high-risk factors. This step involves the establishment of a risk assessment model capable of considering the causality between different risk factors. For example, Li [30] has proposed an improved risk assessment model, as depicted in Figure 2, based on the Multi-Attribute Border Approximation Area Comparison (MABAC) method. Finally, a risk control procedure is conducted to obtain the optimal countermeasure scheme for maintaining a good balance between restraining the high-risk factors and reducing the project's cost. However, due to the systematic construction of deep excavations, and the complexity of the dewatering-induced coupling of the seepage and stress fields, severe accidents related to deep excavations still happen in water-rich areas. Consequently, in-depth investigations into risk management technologies for deep excavations in water-rich areas are urgently required.

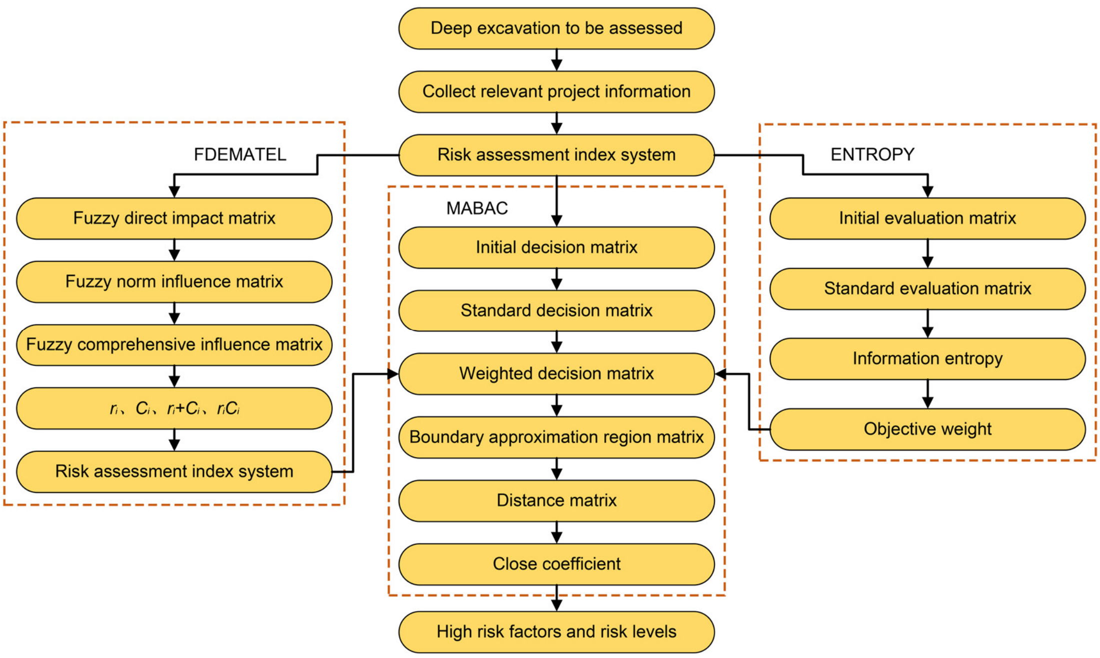


Figure 2. Flow chart of the improved risk assessment model proposed by Li [30].

This Special Issue has attracted many submissions and publications focusing on new and important contributions to the field of risk management technologies for deep excavation in water-rich areas. It contains eighteen articles and one correction. In particular, we are honored and grateful that four articles among them have been awarded the status of 'Feature Paper', a title that indicates advanced research with significant potential for high impact in the field. In the next section, we will briefly describe the contributions of the published articles. More importantly, the purpose of this Editorial is to encourage the readers to actively explore these articles.

2. An Overview of the Published Articles

Tang et al.'s article (Contribution 1) discusses the safety risk assessment method for pedestrian escape in subway stations subjected to flood disasters. Based on an actual subway station engineering project, the authors conducted a series of numerical simulations considering different conditions. A method for calculating the maximum pedestrian capacity, critical flood height, and minimum pedestrian escape speed is proposed. This research is of practical significance for achieving a safe escape from flooded subway stations.

The article by Wang et al. (contribution 2) is focused on analytically predicting the ground surface settlements caused by deep excavations in flood detention zones. The proposed method takes the effect of embankment surcharge load near deep excavations into account. As excessive ground surface settlements are detrimental to the safety of adjacent infrastructures, this method can be used for rapidly estimating the degree of risk in deep excavations in water-rich soft ground.

The third article, from Li et al. (contribution 3), aims to analyze the stability of a deep braced excavation spanning two shallowly buried large-diameter pressurized pipelines. By performing three-dimensional finite element analysis, the deformation and internal force behavior of the excavation support structures were captured. A suspension structure is also proposed for protecting the in situ pipelines and is demonstrated to be effective for reducing the risk of pipeline damage during the construction of deep excavations.

The fourth text published in this Special Issue is a case study by Sun et al. (contribution 4) on the performance of a soft soil deep excavation supported by a composite structural system. The system, comprising SMW piles, concrete struts, and rotary spray anchor cables, is a relatively new excavation support system. By analyzing the performance data from on-site monitoring, the behavior of this excavation support system can be understood, which provides a significant basis for risk control and design optimization.

The article by Yuan et al. (contribution 5) proposes a new machine-learning-based method for identifying the engineering risk of goaf. By performing principal component analysis, both the data-processing speed and prediction accuracy are improved. The risks of goaf are clarified with the help of the support vector machine method. The proposed method is demonstrated to be effective for goaf risk identification.

In the sixth article, Lu et al. (contribution 6) focus on the application of the frequency selection method to shallow groundwater exploration. They established a simplified geophysical model for a low-resistivity conductive sphere in homogeneous half space. The authors proved that the frequency selection method is effective for shallow groundwater exploration.

The research from Shakya et al. (contribution 7) delves into the environmental influences of boreholes installed for the demolition of existing pile foundations. Finite element analysis was performed to determine the ground settlements and distribution ranges for three different soil saturation and loading conditions. This research can provide a reference for risk control during pile removal.

Liu et al.'s study (contribution 8) focuses on water-resisting coal pillars, aiming to comprehend their failure behavior under stress–seepage coupling. A series of stress–seepage coupling tests were performed to investigate the evolution law of the stress–seepage coupling characteristics of coal rock. Based on the numerical analysis results, a method for determining reasonable coal pillar widths is proposed. This study is helpful for risk control in coal seam water inrush.

Liu et al.'s work (contribution 9) is devoted to understanding the effects of mining leachates on the hydraulic performance of geosynthetic clay liners under different temperatures. The research reveals that an increase in the temperature can restrain the ion exchange between bentonite and the mixture. It was also found that the swelling index of bentonite increases with increasing temperature. This research promotes the application of geosynthetic clay liners in mining.

The study by Wu et al. (contribution 10) focuses on a case study of a deep excavation in Lanzhou, China. This deep excavation faced complex environmental conditions comprising a composite stratum, dense buildings, and a high groundwater level. To reduce the safety risks during construction, an automated monitoring system was used. This research is beneficial for risk control practice in similar cases.

The eleventh text published in this Special Issue is the research by Lu et al. (contribution 11) that focuses on detecting the landfill leakage points. The effectiveness and resolution in detecting the landfill leakage points are compared between the opposing-coils transient electromagnetic method and the electrical resistivity tomography method. This article provides a new basis for the detection of leakage points in landfills.

The article by Liu et al. (contribution 12) is a correction to a figure in an article by the same authors (contribution 8). The text "Mongolia" in the initial figure has been revised to be "Inner Mongolia". This correction does not affect the academic content.

Shu et al.'s article (contribution 13) discusses the stability of river embankment seepage affected by underwater shield tunnelling. They performed finite element analysis considering various magnitudes and thicknesses of underwater tunnel overburden. The findings of this study can serve as a guide for reducing the risks of river embankment erosion and seepage instabilities during underwater shield tunnelling.

In the fourteenth article, Wang et al. (contribution 14) report a case history of a deep excavation for the construction of Hefei metro station. The risks associated with this deep excavation, in terms of self-stability, groundwater, and surrounding structures, are assessed. Field monitoring data were analyzed to capture the behavior of the excavation support system and the adjacent buildings. This research is helpful for implementing deep excavation design optimization in similar cases.

The research from Tu et al. (contribution 15) is devoted to investigating the performance of a deep excavation in a water-rich area in Fuzhou, China. This deep excavation is supported by cast-in-place piles combined with internal struts. The dewatering scheme and field monitoring results on excavation performance are elaborately described. This research concludes that tube-well dewatering is effective for deep excavations in water-rich areas.

The article by Wang et al. (contribution 16) is focused on the performance of a deep braced excavation in a thick silty clay stratum. The monitored behavior of the deep excavation, in terms of ground movements, structure deformation, and internal forces in struts, is revealed. Three-dimensional finite element analysis is also performed. The findings from this study provide a reliable scientific basis for risk control.

Chen et al.'s article (contribution 17) proposes a simplified method for estimating the reliability of a three-dimensional slope. This method is within the framework of limit equilibrium analysis. Through two typical slope examples, the effectiveness of the proposed method has been validated. This method can be conveniently used in real engineering practices.

The article by Lu et al. (contribution 18) delves into the applicability of the frequency selection method in the exploration of underground hot water in the Maoyanhe scenic spot. This research is based on a geological investigation in the field and on existing geological data. Using two verification boreholes, the effectiveness of the frequency selection method is demonstrated.

The final article published in this Special Issue is the study by Tu et al. (contribution 19), which focuses on a case history of deep braced excavation in soft soils in Fuzhou, China.

Based on a thorough analysis of the observed performance, the influence of deep excavation on the displacements and internal force characteristics of supporting structures, as well as surrounding buildings, roads, and buried pipelines, is captured. This contribution provides a reference for design optimization and risk control in deep excavations in soft soil areas.

3. Future Research Directions

The nineteen articles published in this Special Issue make a significant contribution to advancing the field of risk management technologies for deep excavation in water-rich areas. Meanwhile, several research gaps can be also detected in exploring the content of these articles, which will direct future research work in this field. For the benefit of readers interested in this field, the guest editors of this Special Issue are glad to present their opinions on several potential directions for further research in the future. The potential avenues that could be explored in the future, in order to achieve a high level of safety in deep excavations in water-rich areas, may include the following:

- An exploration of how seepage and stress fields are coupled during the entire construction period of deep excavation in water-rich areas, and this effects the stability and deformation behavior of the deep excavation;
- The establishment of risk evaluation index systems that are comprehensive, representative, and scientific;
- The development of risk assessment models and methods able to take into account the correlations between parameters and the dynamic evolution of risk indicators during the construction of deep excavations in water-rich areas;
- An exploration of how to shorten the period of risk assessment so as to reserve sufficient time for taking risk prevention measures;
- The optimization of risk control technologies, especially for the methods controlling deep excavation deformation, with the aim of promoting risk control technologies that are more efficient, intelligent, green, and low-carbon;
- The development of a real-time monitoring system and risk alertness forecasting system that can be conveniently used on site in deep excavations in water-rich areas;
- The application of artificial intelligence to specifically enhance the efficiency, precision, and effectiveness, and reduce the cost of risk management technologies, including risk identification, risk assessment, and risk control.

As a final note, we would like to express our sincere gratitude to all the authors of the forty articles submitted for this Special Issue, as well as all the Assistant Editors and Academic Editors of *Water* for their contributions in ensuring its success.

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