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Research progress and prospect of interaction between rock engineering and geo-environments

1. Introduction

In recent years, a large number of geotechnical engineering projects have been completed or under construction in China, such as the Three Gorges Dam Project, Expressway Network Plan, South-to-North Water Diversion Project, West-to-East Gas Pipeline Project, etc. (Wang, 2003; Li, 2010; Huang, 2011; She and Lin, 2014). The construction of large-scale geotechnical engineering not only brings huge economic benefits, but also causes large interference to the lithosphere and hydrosphere that we rely on for survival (Wang et al., 2005). This paper focuses on the interaction mechanism of rock engineering and geo-environments in the fields of urban underground space utilization, natural gas hydrate exploitation and high-level radioactive waste disposal. The current problems and future development in these fields were discussed. The researcher can get a quick understanding on the concept of interaction between rock engineering and geo-environments and pay more attention to the geo-environmental protection.

2. Influence of urban underground space utilization on the surrounding environments

Currently, the effective development and utilization of urban underground space is becoming a hot issue. Many developed countries have focused on the construction of an integrated underground city. China has also invested a great deal of manpower and various resources in the development and utilization of urban underground space.

In the development of urban underground space, the influence of construction on the surrounding environments and groundwater must be fully considered. Otherwise, heavy disasters will be induced (Jiang et al., 2009; Zhang et al., 2014; Cai et al., 2015). The accidents in urban underground space always cause more serious consequence than other engineering projects do. For instance, the sand flow accident that occurred during the construction of Shanghai Metro Line 4 resulted in a wide range of ground subsidence and a large number of building damages around the accident site area were induced.

The major scientific issues in urban underground space development are summarized as follows: formation damage and deformation characteristics under construction disturbance, dynamic interaction mechanism of ground and structure, safety assessment and control of urban underground engineering, evolution of underground structure performance under dynamic spato-temporal environmental effects, status perception and assessment of long-term underground structures, and self-repair mechanisms and control theory of groundwater.

3. Potential geological disasters from natural gas hydrate exploitation

Natural gas hydrate ($CH_4 \cdot 5.75H_2O$), also called methane ice, methane hydrate, or gas hydrate, is a solid clathrate compound in which a large amount of methane is trapped within a crystal structure of water, forming a solid similar to ice. Significant deposits of methane clathrate have been found under sediments on the ocean floors of the Earth. The global storage of natural gas hydrate can almost meet the energy needs of mankind for nearly 1000 years, and therefore it is considered to be new energy resources. As a kind of clean energy, natural gas hydrate has received more and more attentions around the world in recent years.

A large number of geotechnical problems, especially the potential geological risks during production, exist in the production of gas hydrate as it is reserved in the submarine sediments around 300–4000 m under sea level. Experimental results show that gas hydrate decomposition can cause strength reduction of sediments, changes in the structure and degree of consolidation (Hyodo et al., 2005; Kimoto et al., 2007). These factors are likely to cause occurrences of undersea landslides and other geological disasters. The undersea landslides in Columbia continental shelf, American Pacific coast, Sea of Japan and Mediterranean are speculated to be associated with the decomposition of natural gas hydrate. Large undersea landslide is a direct threat to drilling rigs and undersea cables, and may further lead to tsunamis and greenhouse gas leakage, resulting in a significant impact on the seabed and the global environments.

In order to realize safety production of natural gas from hydrate reservoir, a systematic research should be conducted, which involves studying mechanical behavior of hydrate-bearing sediments before and after exploitation, performing physical experiments and numerical analyses to understand the behaviors of gas hydrates during dissociation processes, then analyzing solid matrix deformation induced by gas recovery and its influence region, and finally building theoretical system for predicting the mechanical stability of seabed ground and potential geo-hazards. Formation and dissociation experiments of artificial gas hydrate under various pressures and temperature conditions should be conducted to understand the formation mechanism, dissociation kinetics, conservation of energy, multi-phase flow and heat transfer processes during formation and dissociation of gas hydrate. Coupled thermo-hydro-mechano-chemical (THMC) models should be established taking into account the gas–liquid–solid phases involved in gas hydrate. Numerical simulations should also be applied to study the whole process of gas hydrate production and

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its influences on the submarine environments to establish the geological disaster control theory for gas hydrate production.

4. Challenges in high-level radioactive waste disposal

High-level radioactive waste management concerns disposal of highly radioactive materials created during production of nuclear power. High-level radioactive waste requires sophisticated treatment and management to successfully isolate it from the biosphere. There are many factors that can lead to nuclear leakage, such as the crustal movement, groundwater seepage, human activity, earthquakes and so on. Governments around the world are considering a range of waste management and disposal options, although there has been limited progress toward implementing long-term waste management solutions. This is in part due to the time frames in question when dealing with radioactive waste range from 10,000 years to millions of years, according to the studies based on the effect of estimated radiation doses. With the rapid development of China's nuclear industry, the safe management and disposal of high-level radioactive waste are also becoming a major safety and environmental issue.

In the project of high-level radioactive waste disposal, the potential leakage and migration of radionuclide should be analyzed in advance. There is a debate over what should constitute an acceptable scientific and engineering foundation for proceeding with radioactive waste disposal strategies. Some scientists insist that deep geological repositories in stable geological formations are necessary. National management plans of various countries display a variety of approaches to resolving this debate. It is widely accepted that spent nuclear fuel and high-level reprocessing and plutonium wastes require well-designed storage to minimize releases of the contained radioactivity into the environments.

The countermeasures which should be adopted during site selection, design and construction of waste disposal sites remain as an important subject. The basic concept is to locate a large, stable geological formation and use mining technology to excavate a tunnel, or large-bore tunnel boring machines to drill a shaft 500–1000 m below the surface where rooms or vaults can be excavated for disposal of high-level radioactive waste (Heltona et al., 2012; Wang, 2014). The goal is to permanently isolate nuclear waste from the human environments. However, many people remain uncomfortable with the immediate stewardship cessation of this disposal system, suggesting perpetual management and monitoring would be more prudent.

5. Conclusions

Research on interaction between rock engineering and environments is arousing more and more scientists' attention, and develops into a new mechanics with special attention to the influence on ground environments. The new subject is developing with high speed, and it will be more powerful in solving problems at industrial sites. The new subject requires us to consider the interaction between the structure and the geo-environments, rather than unitary structural strength. The developing of the new subject can provide a scientific basis for the relevant construction projects, especially in the fields of human-induced environmental changes prediction and protection. The current problems, the hot topics and developing direction pointed out in this paper will give the researchers a reference for solving the significant influence of rock engineering on the geo-environments.

Conflict of interest

The authors wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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