Engineering Geology 195 (2015) 16–27

Contents lists available at ScienceDirect

Engineering Geology

journal homepage: www.elsevier.com/locate/enggeo

Technical Note

Mitigation of geohazards during deep excavations in karst regions with caverns: A case study

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ARTICLE INFO

Article history:
Received 24 January 2015
Received in revised form 15 May 2015
Accepted 23 May 2015
Available online 27 May 2015

Keywords:
Karst
Diaphragm wall
Deep excavation
Hazards

ABSTRACT

Karst landscapes are widely distributed and different characteristics are displayed in different regions due to the effect of various natural environmental factors which occur throughout China. Buried karst cavern systems covered by sandy strata, which are widely distributed in Guangdong Province, possess the following features: high fissure water content, high rock permeability, susceptibility to collapse, variability in shape and an irregular distribution. Socket diaphragm walls are usually adopted to retain soil and to cut-off groundwater during deep excavations in Guangdong Province, for the safety of the excavation and to reduce the impact on the surroundings. However, geohazards often occur during the construction of diaphragm walls in karst regions, causing problems such as diaphragm wall collapse, water or mud ingress, ground collapse and long-term instability. An eight-step treatment technique is proposed, which involves filling the karst caverns before the construction of diaphragm walls. A case study using the treatment technique in Maanshan Park Station on Guangdong Metro Line 9 is also presented. Leakage of the diaphragm wall was observed during the excavation, and grouting failed to seal the leakage. The mechanism of the leakage process was analysed and countermeasures were undertaken.

1. Introduction

Karst topography is a landscape which has formed as a result of the dissolution of soluble bedrocks, which are usually carbonate rock (e.g. limestone, dolomite), sulphuric rock (e.g. gypsum, mirabilite), and halogenated rock (rock salt) (Lu, 2010). Geological hazards, such as sink holes, water ingress and ground collapse can occur during engineering construction in karst regions (Yuan, 1976; Li and Du, 2004; Yilmaz, 2007; Lu, 2010; Li et al., 2013; Huang et al., 2013; Cui et al., 2015). It is therefore important to investigate the formation of the karst geology and to assess the geohazards before construction activities for hazard management and land use planning. Furthermore, the mitigation of geohazards and the treatment of the karst caverns are of great significance for the prevention of damage. Therefore, it is essential to study karst geology and to take effective countermeasures to mitigate geohazards during deep excavations in karst regions with caverns.

Karst is widely distributed throughout China. The characteristics of karst vary due to the effect of various natural environmental factors found in China. In general, there are two kinds of karst: pure karst, which is carbonatite karst, and composite karst, which includes sulphates and halides. Buried karst with caverns, formed from pure karst, is widely distributed in Guangdong Province, which is located in the southeast karst area of China. Buried karst caverns with high fissure water content, high permeability, an irregular distribution, and of variable shapes, are prone to collapse.

With the recent economic development and urbanisation of Guangdong Province, the infrastructure has been developing rapidly, including the metro system and other projects involving deep excavations (Tan and Wang, 2013a,b; Shen et al., 2006, 2009, 2010, 2014; Xu et al., 2012a,b; Wu et al., 2014; Yilmaz and Marschalko, 2012; Bolton et al., 2014; Dong et al., 2014; Raychowdhury and Jindal, 2014). During the construction of metro stations in China, the following three types of strata are often encountered and researched: soft soils (clay, silt, and sand), sand and gravels, and mixed ground (Xu et al., 2013a,b; Zhao et al., 2007; Tóth et al., 2013; Fargnoli et al., 2013). But deep excavations in karst regions have not been discussed extensively in the existing literature (Huang and Huang, 2009; Li and Du, 2004; Luo, 2012; Zhang et al., 2012; Shen and Xu, 2011; Shen et al., 2013a,b,c; Marschalko et al., 2012a,b,c).

In recent years, the construction of an increasing number of metro stations has involved the installation of socket diaphragm walls to support the excavation because they are generally safe, of high quality, have good waterproof capability and low impact on the environment. In karst regions, the karst caverns should be treated before the construction of a diaphragm wall for the stability of the excavation. At present, the main methods to treat the karst caverns include the clearance-filling method, the beam-bridge method, dynamic compaction, jet grouting and sleeve-

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http://dx.doi.org/10.1016/j.enggeo.2015.05.024
0013-7952/

valve-pipe grouting (Yuan, 1976; Li and Du, 2004; Lu, 2010; Luo, 2012; Zhang et al., 2012; Huang et al., 2013). In the reports describing these methods, only the reinforcement of karst caverns with slurry has been discussed. Since effective treatment, including the depth and the layout of the grouting holes, to karst caverns around diaphragm wall is absent, the loss of slurry and concrete cannot be guaranteed. However, if there is no effective treatment of the karst caverns around the diaphragm wall, which takes into account the depth and the layout of the grouting holes, then slurry and concrete may be lost. Therefore, the existing methods cannot be adopted in the treatment of karst caverns.

Karst caverns which are located in the construction area of deep excavations will impact on the stability of those excavations. In order to reduce the difficulty and risk in construction, the treatment of karst caverns before the construction of diaphragm walls should be undertaken. The objectives of this paper are as follows: (*i*) to describe the distribution of karst in Guangdong Province (*ii*) to discuss potential geohazards during diaphragm wall construction in karst regions with caverns; and (*iii*) to introduce a karst cavern treatment technique.

2. Sand covered karst cavern in Guangdong Province

The formation of a karst system (Yuan, 1976), which can exert a huge impact on the features of both the surface and the subterranean environment, is a long process, and a karst system can be hundreds of kilometres in length. At the start of the formation, microkarst corrosion occurs and results in voids with diameters of 0.1–5 cm. The erosion continues with the passage of time and makes the voids extend and develop into channels. Once these channels are connected, a karst system is formed.

According to the exposure conditions, karst can be divided into exposed and semi-exposed karst, and buried karst. Due to underground construction, such as deep excavations, usually being conducted around

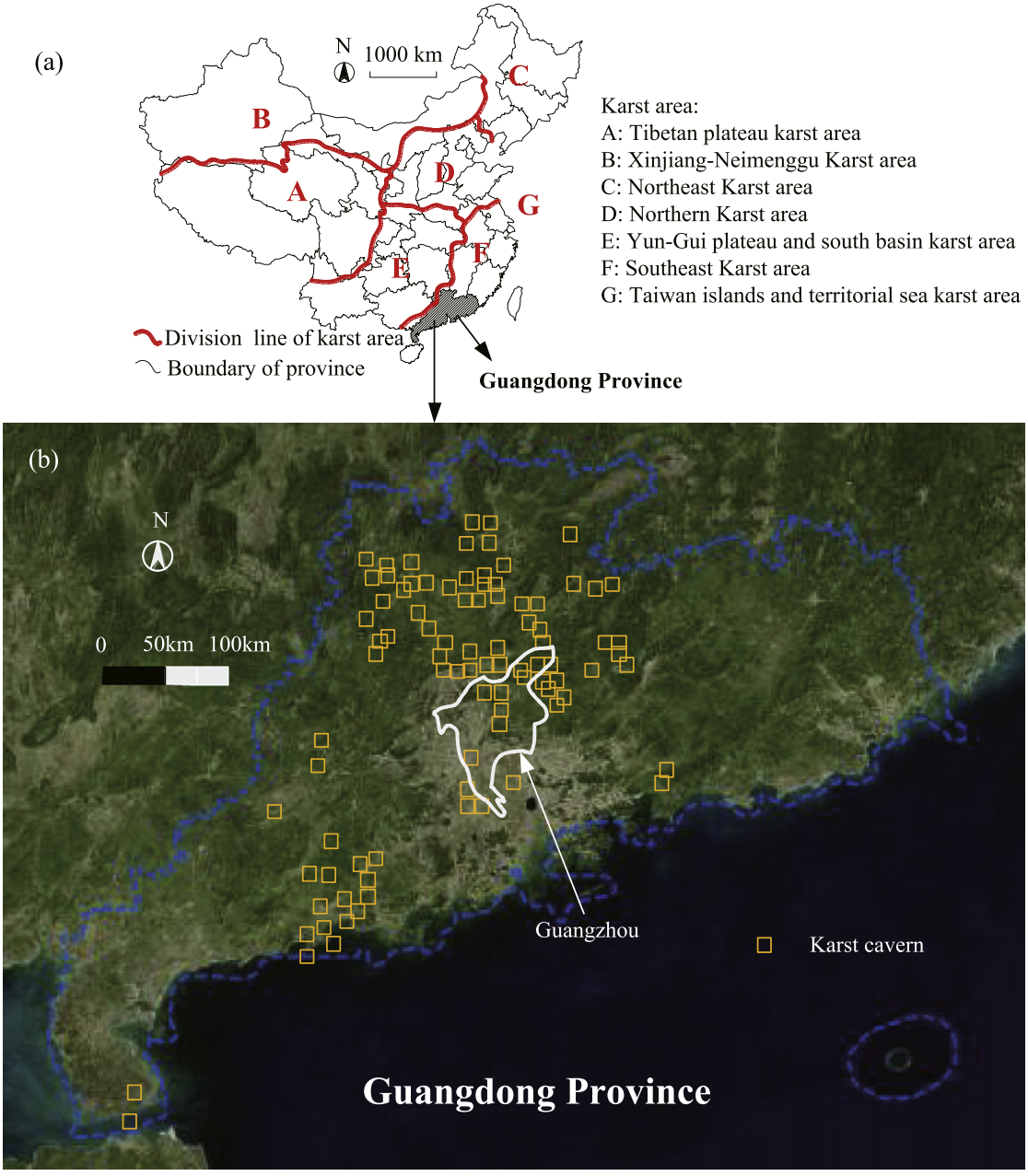

Fig. 1. (a) Karst zoning map of China. (Created based on CK2010) (b) Plan view of karst caverns in Guangdong Province. (Created based on Ma, 1997).