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Proposing a framework to combine geological and geotechnical information for city planning in Sanandaj (Iran)

Behrooz Samadian [a,*], Ali Fakher [b]

[a] Department of Civil Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran
[b] Department of Civil Engineering, University of Tehran, Tehran, Iran

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ABSTRACT

A proposed framework that combines geological and geotechnical characteristics is very useful in planning and designing construction activities in a large area, such as a city. A step-by-step process of the proposed framework is presented for the city of Sanandaj, Iran. Sanandaj was developed on Cretaceous rock units as well as Quaternary alluviums. Identifying engineering variables related to these rock units and alluvial deposits is essential for determining their behavior in construction projects. In the presented research, first, all rock types and alluvial layers in Sanandaj were determined and their properties, including their formation and origin, were described, and then, the area was geologically classified. A database including the results of 211 geotechnical boreholes at Sanandaj was compiled and data were completed and validated through the excavation of 9 pits in different locations around Sanandaj. Finally, a geological and geotechnical framework was proposed for Sanandaj to identify the city's underlying geological layers.

1. Introduction

Identifying the ground geotechnical properties in a large area by engineering tests and borehole drilling is very difficult because it is expensive and time consuming. The identification of large areas initially requires geological studies followed by the inclusion of geotechnical information. Finally, a geological and geotechnical classification is prepared for the entire area. This type of classification might not only be used in urban planning and regional development, but it might also be applied in the quick selection of geotechnical variables and initial designs in small-scale projects. Furthermore, these types of studies provide useful information on the effects of construction projects, on the possible changes in environmental conditions and on the surrounding landscape. In this paper, an example of such a classification process is presented for Sanandaj, the capital of Kurdistan province. The city of Sanandaj is situated in the west of Iran covering an area of 80 km^2 and is economically important due to its vicinity to Iran–Iraq border. From 2006 to 2011, the population of the city has grown from 330,000 to 400,000. The Sanandaj site is a combination of rock and soil layers, which is an interesting and complicated site for such a study. In Fig. 1, the location of Sanandaj and its main roads are shown. Construction in this city is rapidly expanding due to population growth and urban development. Because Sanandaj is located in a large valley and surrounded on all four sides by high mountains, there is limited potential for the development of the city surface area, which has resulted in an increase in the number of buildings' floors as well as the construction of deep basements. An increase in the heights of buildings and the depths of excavations increases the importance of identifying the ground geotechnical properties of this city. To ensure that the urban development in Sanandaj is conducted with an in-depth understanding about the city's geotechnical conditions, it is very important that a geological and geotechnical classification be prepared. In this research, major geotechnical studies on Sanandaj are presented.

2. Similar research

Geological and geotechnical classification of urban areas has been proposed at several sites. Here we provide a brief overview on some of these researches, which were used as examples in this study. Tehran's coarse-grained alluvia have been divided into four geologic categories (Rieben, 1966). In the Rieben (1966) the geological classification system of the age and general geological characteristics of alluvia are considered. Fakher et al. (2007) added geotechnical characteristics to the Rieben geological classification system, and consequently, a new geotechnical–geological classification was presented for Tehran's soils, which is widely used in Tehran. Cheshomi et al. (2009) investigated the influence of grain shape factors on the friction angle of Tehran's soils and recommended empirical relations for Tehran's soils in various geological zones. Skipper et al. (2005) identified geological properties of the Quaternary deposits in Dublin and presented the characteristics and hazards of clay in this city. In another similar study, Maharaj (1995) combined the geological and geotechnical information to identify the physical and mechanical properties of Jamaican soil and evaluated the

* Corresponding author.
E-mail addresses: b_samadian@yahoo.com, b_samadian@iausdj.ac.ir (B. Samadian).

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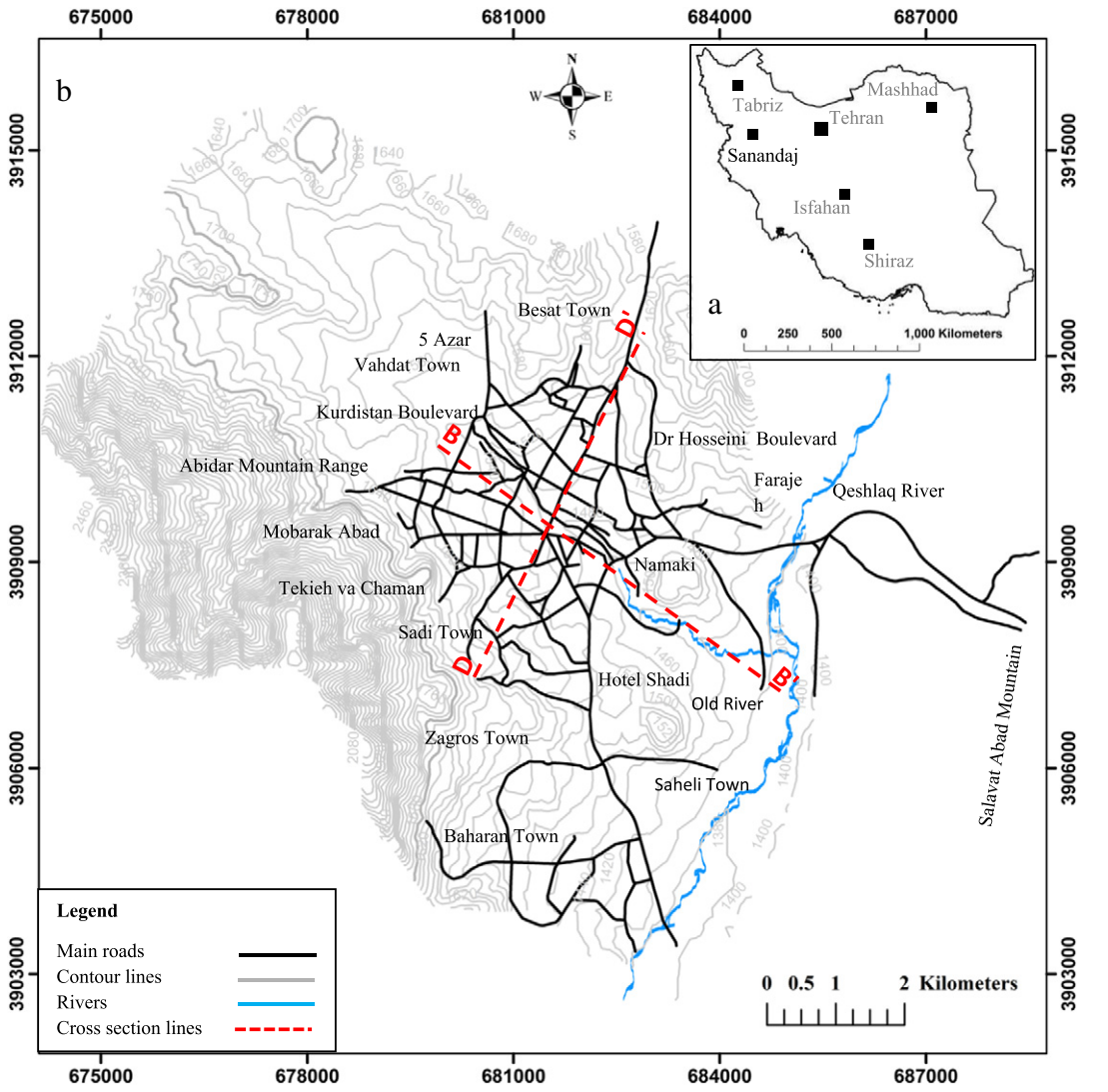

Fig. 1. a) Map of Iran, including main cities. b) Map showing the location of roads in Sanandaj and trace of the sections presented in Fig 7.

geotechnical hazards of Jamaican soil. Geotechnical studies on the development of Suez were conducted in Egypt by Arnous (2011) to develop the selection and construction of appropriate sites. Fuchu et al. (1994) conducted an engineering geological study on Tong Chuan in China, whereby the research, geotechnical, and geological problems of the city were investigated along with the problems induced by construction activities, such as the constructed slopes. Additionally, several urban geological-geotechnical studies have been conducted for some cities, aimed at understanding the interplay of natural processes and urban development (Haworth, 2003; Raspa et al., 2008; El May et al., 2010; Touch et al., 2014; Jannuzzi et al., 2015).

3. Steps of the proposed framework

The proposed framework for combining geological and geotechnical information of the Sanandaj site was conducted in six steps, as presented in Table 1. These steps are described in the following sections.

3.1. Step one: studying the general geology of the considered area

The study area is located in a highly active seismic zone, not far from the Main Recent Fault in the Zagros fold and thrust belt. Floods and

Table 1
Steps considered in the proposed framework.

Step	Title	Purpose
1	Geological desk study	Identifying basic geological characteristics and origins
2	Determining apparent evidence from field visits	Determining rock units and soil layers with outcrops and studying their appearance
3	Understanding the subsurface layers	Determining the layers and drawing the transverse and longitudinal profiles of the considered area
4	Geological classification	Determining the geological units of the area and their formation
5	Determining geotechnical properties of the geological units	(i) Collecting the available geological information for each geological unit (ii) Controlling the available information (iii) Completing the information for unknown units
6	Presenting the geological and geotechnical classification for the studied area	(i) Determining a geological-geotechnical classification (ii) Determining the geotechnical hazards