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Engineering geotechnical investigation for coral reef site of the cross-sea bridge between Malé and Airport Island

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ABSTRACT

The Malé-Airport Island Cross-sea Bridge project is the largest island-linking project in Maldives, the country known as "the kingdom of coral reefs." Coral reef is also a special type of rock and soil medium to support significant civil engineering projects. In the Cross-sea Bridge project, the engineering geotechnical investigation of the coral reef site was divided into two stages: the feasibility study and the construction-drawing design phase. Engineering geological survey techniques were applied, and together with field exploration methods, such as geophysical prospecting and drilling exploration, the geological conditions of the site with respect to bridge engineering demands were comprehensively evaluated. In addition, the design parameters for pile group foundations were proposed based on in-situ tests, such as standard penetration, dynamic sounding, and acoustic wave testing in borehole as well as laboratory physical and mechanical experiments and bearing-capacity tests for pile foundations using rock and soil samples drilled from the site. The investigative methods adopted in the Malé–Airport Island Cross-sea Bridge project and the results obtained will provide references for similar engineering projects in the future.

1. Project overview

As a construction project for which China provides a significant amount of aid, the Malé-Airport Island Cross-sea Bridge project in the Maldives is on the critical path to realizing the 21st Century Maritime Silk Road envisioned in China's "One Belt, One Road" initiative. The project is located in North Malé Atoll, Maldives, which crosses the Gaadhoo Koa Strait and connects three adjacent islands, Malé Island, Airport Island, and Hulhumalé (Fig. 1) which are both in the atoll. The project is the most important island linking project in the Maldives.

The project starts in the southeastern corner of Malé Island, connects to a construction plan known as Boduthakurufaanu Magu Road in the southern side of Malé. Then a bridge is designed to cross Gaadhoo Koa Strait from the end of Boduthakurufaanu Magu Road and make landfall on the southern side of Airport Island. The endpoint of the bridge connect to the road from the airport to Hulhumalé. The wide of the project is 21.0 m. And total length of the project is approximately 2 km, with the bridge being 1.39 km long and the total bridge approaches being 610 m long.

The proposed foundation of the bridge is a type of pile group foundation known as "overall steel tube" or conventional large-diameter pile group foundations known as "separated steel tube". Both types of pile group foundation consist of six pieces of 1.5-m-diamter drilled piles.

The bedrock in the proposed project area is composed mainly of coral reef sediments, a special type of rock and soil medium. Coral reefs are geological sediments formed by accumulation of skeletons and shells of dead reef-building corals, which are primarily distributed in the tropical ocean between the Tropics of Cancer and Capricorn (Wang et al., 1997). On this type of bedrock, engineering projects are also distributed (King and Lodge, 1988; Hua, 2015; He et al., 2010; Yuan et al., 2012) (Table 1). Their special nature is embodied by two aspects of specificity. Initially, the material composition of coral reef sediments are basically $CaCO_3$. Additionally, they are formed by organisms in the marine environment. In relevant specifications of geotechnical engineering projects in China, coral reefs have not been included for consideration, and previous studies have shown that this type of rock and soil medium has the following major characteristics: (1) the size and shape of sedimentary particles show a relatively large variability, leading to a relatively large spatial

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Fig. 1. Location diagram showing the proposed project.

Table 1
Engineering projects constructed on coral deposits.

	Country	Position	Project name	Construction purpose	Foundation form	Construction time
1	Australia	North west shelf of western Australia	North Rankin "A" Offshore Gas Platform	Gas extraction	pile foundation in the sea	From 1972/3 to 1987/8
2	Saudi	East bank of Red Sea in Rabigh	Saudi RABIGH 2 × 660 MW Power Plan	Oil-fired power plant	Natural base foundations or Partial replacement	From 2009/2 to 2013/1
3	Saudi	East bank of Red Sea in Jeddah	Saudi RSGT Port Project	Container terminal	Reinforce foundation	From 2008/1 to 2009/12
4	Sudan	West bank of Red Sea in Sudan Port	New Container Terminal Project in Sudan Port	Container terminal	Reinforce foundation	From 2006/6 to 2009/11

variability in the distribution of porosity in the sediments; (2) the porosity is far higher than that of terrigenous sediments; (3) the strength of the particle is lower than that of quartz particles, and due to the existence of intergranular pores, making it fragile; (4) sediments can easily experience deuteric alteration such as cementation, and after being cemented, the cementation degree and the type of the sediments structure significantly influence the engineering properties (Given and Wilkinson, 1985).

Since there had never been such a large-scale island-linking project undertaken in the local area, therefore, the implementation of the project is undoubtedly a huge challenge for geotechnical engineers.

2. Investigative methods and work assignments

According to Provision No. 6.11.3 in the "Code for Highway Engineering Geological Investigation" of People's Republic of China Industry Standard JTG C20-2011 (The ministry of transport of the people's republic of China, 2011), the exploratory points basically focus on the proposed piers (Fig. 2). The entire investigation process can be divided into two stages: the feasibility study and the construction-drawing design.

The major tasks during the feasibility study which is lasted from May 20, 2015 to June 13, 2015 included engineering geological survey,