

Geotechnical characterization of Macau marine deposits

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ABSTRACT

Samples of marine deposits retrieved at an onshore old reclamation site on the north coast of Taipa, Macau were studied. Samples located from 6 m to 17 m below the existing ground were retrieved from three boreholes where field vane shear tests were performed close to one of them. The soil is very soft and the results reveal that the deposits are normally consolidated. In addition to common geotechnical classification tests, X-ray diffraction and scanning electron microscope analyses were carried out. Oedometer tests, K_0 -compression and undrained triaxial shear tests were performed on intact as well as laboratory remolded specimens. The deposits resemble typical soft clay behavior in terms of compressibility and permeability. However, the soils exhibit a surprisingly high K_0 -value which is believed to be caused by the presence of salts during the sedimentation process. Critical state of the soil is presented and two unique critical state lines in the $e - \ln p'$ space are found for the deposits at different depths.

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1. Introduction

Located in the estuary of the Pearl River in the south China, 60 km west of Hong Kong and facing the South China Sea, Macau was a Portuguese administered enclave since the early 16th century until her handover to China in 1999. Since then, Macau is experiencing the fastest development in her history. Construction of residential and commercial buildings, infrastructure development and casinos can be found throughout the city. Macau has a total area of only 29.2 km² with a population of more than 520,000 in 2008. Developed on marine deposits of varying thickness, ranging from a few meters to more than 20 m, which then overlying alluvium and saprolitic soils, Macau consists of the Macau peninsula itself and two islands, Taipa and Coloane, which were then united in the 1990s through large-scale reclamations (Fig. 1). Regardless of its rapid development in the last decade, a systematic record on the soil properties is neither available nor accessible. The data is either kept by government bureaus or local construction companies which is usually very difficult to access, if still possible.

This paper briefly introduces the geological situation of Macau, followed by presenting a geotechnical survey on an onshore site in Taipa as shown in Fig. 1. The site is located on the north coast of Taipa. Reclamation of the area was finished for more than 15 years and the site was idle since then. The investigation included boring of 100 mm diameter samples in 3 boreholes (BH1 to BH3) and in-situ vane shear

tests at different depths. Standard classification tests, X-ray diffraction and scanning electron microscope analyses were performed. A series of laboratory tests including oedometer tests, K_0 -compression as well as triaxial undrained compression tests were also carried out. The results are compared to available literature in other major cities as well as limited accessible data in Macau. The main aim is to study and present the geotechnical properties of the marine deposits in Macau which provides a systematic set of reference data for future investigation/development in the area.

2. Geological profile

Continual reclamation since the 17th century changes Macau to a generally flat terrain of about 29 km². Yet, the original natural landscape can still be revealed by several small hills scattering around. Similar to Hong Kong, Macau is subjected to a humid subtropical climate which favors chemical weathering. Nevertheless, formation of marine deposits in Macau is believed to be very different from Hong Kong. In Macau, Pearl River is the major source of sediments as indicated by the turbid water around the coast. Incessant dredging of navigational channels is necessary to maintain Macau's marine accessibility. On the other hand, Hong Kong is protected by its prevailing currents as indicated by its clear waters such that little Pearl River sediment is carried into the territory of Hong Kong. Local erosion products washing down into the sea, however, are the major source of sediments in Hong Kong marine deposits (Lumb, 1977).

The geological profile at the present site is similar to that of other onshore areas in the territory of Macau. A layer of general fill of 6 m to 8 m thick was placed on marine deposits, which in turn overlaid an

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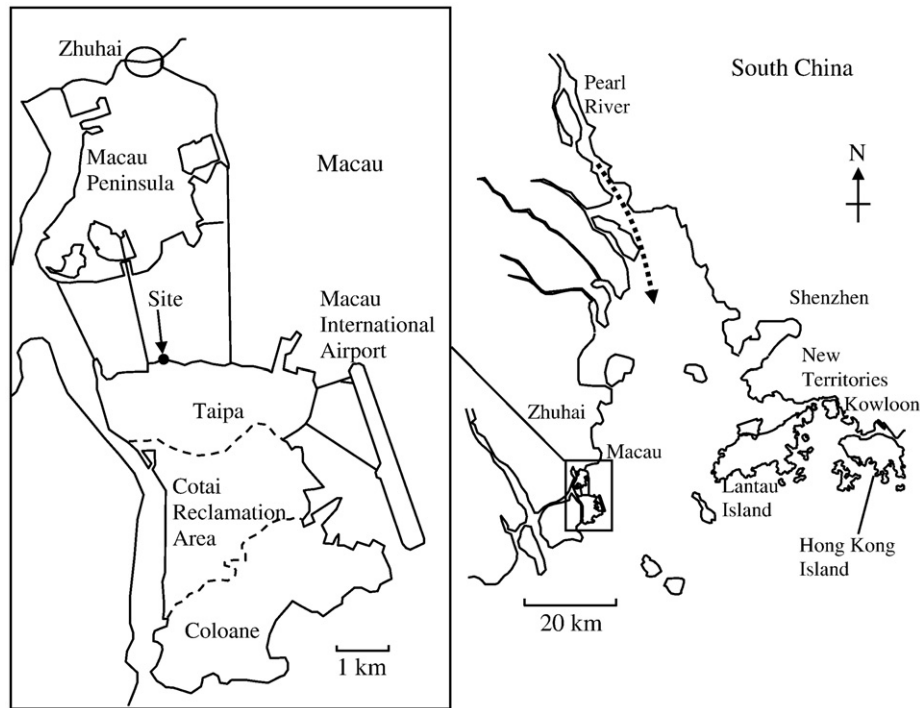


Fig. 1. Location of Macau.

alluvial and residual soil stratum. The thickness of the marine sediments is about 10 m as shown in Fig. 2. The maximum water level in the reclamation area is 1 m below ground with tidal fluctuation of ± 0.5 m. Generally, the marine layer is soft and is composed of an inhomogeneous clayey silt deposits with some bands of sand lenses and granular layers. The occurrence of sand lens makes sample retrieval extremely difficult which will be further elaborated in a later section. Shell fragments are found throughout the deposits. Fig. 3 shows a marine soil sample retrieved from BH3-2. Shell fragments and sand lens can be readily seen which is common to all samples taking from the site. The

marine sediment varies from brownish yellow to dark gray. The smell and dark gray color of the marine deposit indicate that the sediment may contain an appreciable organic content.

3. Samples and index properties

3.1. Sampling

The K-200 Geonor thin wall stationary piston sampling tube was used to obtain soil samples in the site. The sampler is made of stainless steel, having a tube thickness of 2 mm, an internal diameter of 100 mm and 800 mm in length. However, the open tubing method,

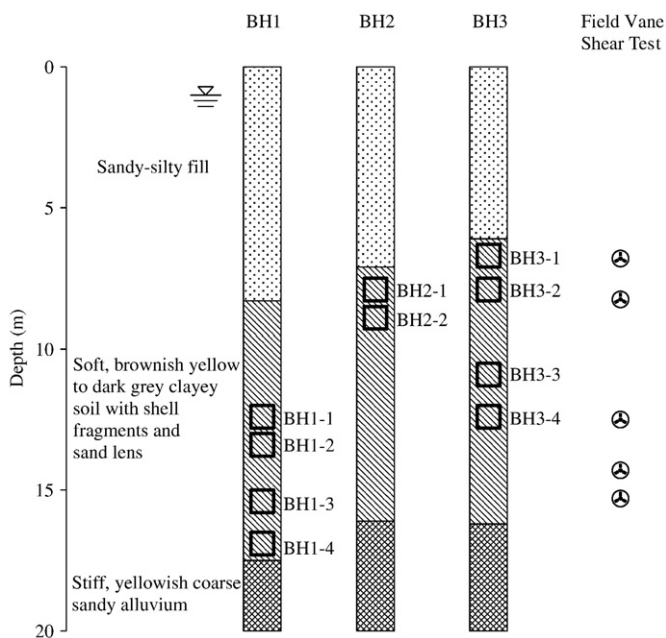


Fig. 2. Geological profiles at the site.

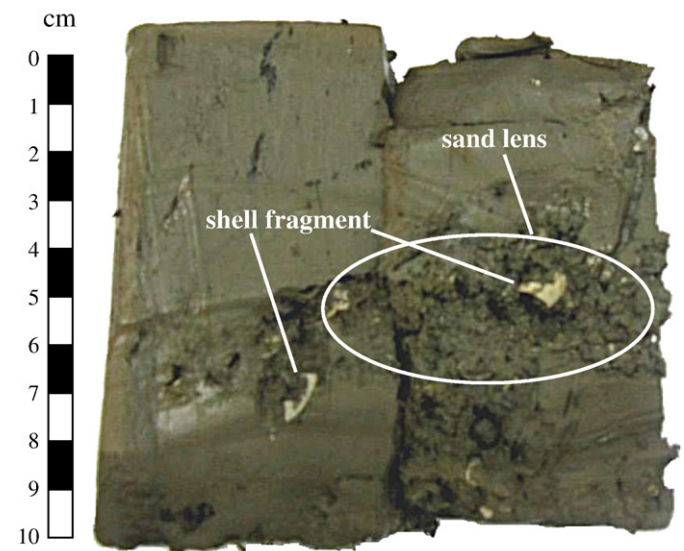


Fig. 3. Shell fragments and sand lens in marine deposit (from sample BH3-2).

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