

GROUND INVESTIGATION GUIDELINES 04.7 - KARST IN HONG KONG

What do we need to know?

General Information

- What is to be built and where (roads, tunnels, reservoirs, utilities, foundations, sensitive structures - tolerance to movement, extent of stress bulbs and likelihood of water leakages causing dissolution)?
- Will the development impact upon the stability of existing structures?
- Existing (damaged/disrupted) utilities actively reactivating dissolution? Evidence of natural ground or structural subsidence/damage due to subsurface dissolution? (crown hole development, swallow holes, caves, cracking or repointing of mortar/masonry, window or door frame misalignment.)

Geological Model

- The geological model is of paramount importance.
- Any investigation should attempt to determine whether there are, or are likely to be, any significant solution features in the rock mass.
- If solution features are expected or identified, how large are they, how deep do they extend and what is the nature of the infilling, if any. Inclined drillholes should also be considered.
- Scope GI carefully: use of SPTs in cavities, recording depths and quantities of drilling flush loss and fluctuations in flush pressures, recording penetration rate and identifying any significant or immediate drop in drilling rods (ensure recovery in cavity zones).

Hydrogeological Model

- Groundwater and surface water hydrology should be at least broadly characterised and the likely changes induced by the engineering works should be predicted.
- Avoid insitu permeability testing that could encourage washing the infill

Scheme layout drawings

Background study of available records
Local dilapidation and existing utilities survey

Site Investigation & Engineering Geophysics.
Use experienced supervisory staff (preferably Cat. I supervisor with experience in Karst GI)

Geotechnical Instrumentation

Ground Investigation

Drillhole Sampling

Superficial cohesive soils: U100/76 or Mazier
Superficial granular soils: U100/76
Rock: minimum 80mm diameter, triple-tube air foam drilling in weaker and more decomposed rock
Groundwater sampling

Drillhole Testing

SPTs (looking for low values bounded by hard rock) permeability tests in cavity infill should be considered only for special circumstance

Engineering Geophysics Options

Microgravity, gravity
Cross-hole seismic
Gamma logging

Instrumentation

Standpipes to define the water table above rockhead and piezometers to determine pressure levels in cavity infill

Typical Properties to be determined

Weathering Grade

Knowledge of the weathering grade on a mass scale (i.e. zonal classification) is fundamental to understanding Karst, and identifying the presence of Karstic features

Classification Schemes and Weathering of Carbonates

The six-zone classification scheme given in Geoguide 3 is intended for use in the igneous granite and volcanic rocks found in Hong Kong. It is not appropriate to calcareous rocks since weathering is mainly due to dissolution and not mineral decomposition. More detail is given in Ch14 & 16 of AGS 2004 Publication: Geology of Site Investigation Boreholes.

- Properties of superficial materials (typically alluvium, marine sediments, Karst surface (debris flow) deposits)
- Properties of underlying rock i.e.
 - a) Identification of cavity's extent & infilling;
 - b) Identification of floating rock lenses within a large cavity soil infill;
 - c) Identification of rockhead for founding of piles
- Surface and groundwater characteristics

Strength and permeability of superficial soil horizons – Unconsolidated Undrained triaxial and lab 'K' tests

Nature, strength and degree of decomposition of underlying rock, triaxial, UCS, point load strength.

Chemical properties of existing or imported fill and foundation materials and groundwater

Chemical Tests
PH, SO₄, Cl

Typical Required Data Marble Quality Designation (MQD)

MQD is a risk based approach to interpret GI data and classify marble masses into 5 zones reflecting foundation suitability.

MQD = Average RQD x Marble Rock Recovery Ratio (MR)

Full definitions and guidelines are given in GEO Report No. 29.

The depths of drillholes should relate to the depth of marble bedrock and the magnitude of the load to be applied by the structure. If marble is encountered, a minimum penetration of 20m into sound marble rock is recommended in order to reduce the risk of existing cavities not being identified.

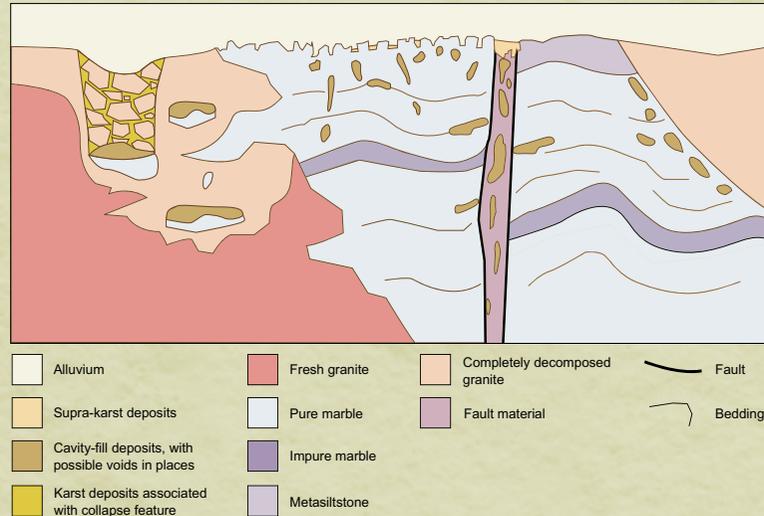
Karst : Geological Impact

Karst is a term used in Hong Kong, to describe carbonate rocks containing dissolution features and exhibiting highly irregular rock surfaces. The magnitude of the dissolution features is a function of the purity and thickness of the marble, and the prevailing hydrogeological conditions over the geological history of the rock mass. Cavities, sometimes several metres thick, with or without typical silty/clayey infill have been encountered within the zone of influence of engineering structures, in identified Karstic areas. The presence or expectancy of encountering such features has had a major impact on the design and construction of foundations in these areas. Marble is encountered at least 20m below ground and is usually capped by low permeability superficial deposits and little to no dissolution occurs

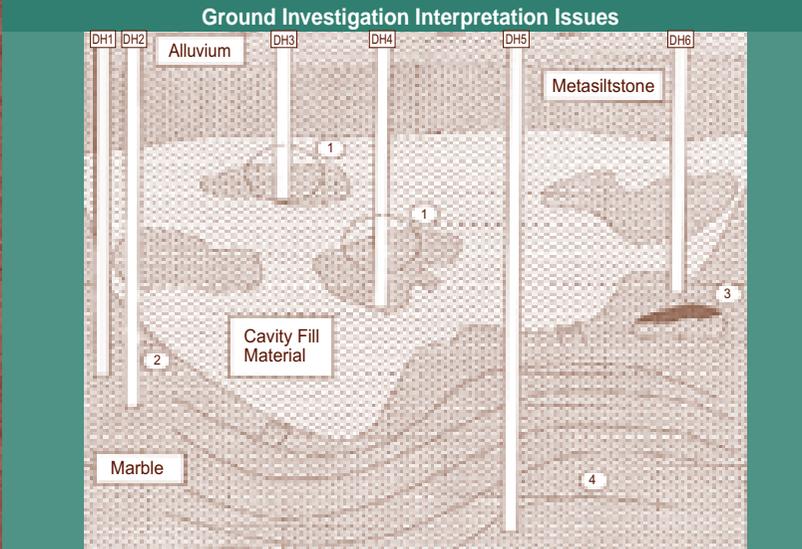
Karst : Government Guidelines

Metasedimentary strata include marble, outcrop and subcrop in the Northwest New Territories (Yuen Long to Lok Ma Chau, the Northshore Lantau area, near Tung Chung and Ma On Shan) areas of Hong Kong. Marble clasts, sometimes metres across, are also present in the volcanic formations of the Tuen Mun area. The presence of cavities, within some of the marble units, has led to the designation of the Northwest New Territories and Ma On Shan as Scheduled Areas 2 and 4 under BD PNAP161 (as well as the issue of the GEO TGN12 "The Designation Area of North Lantau"), respectively, under the Buildings Ordinance. It has also focused attention on the presence of Karstic features as a constraint in engineering development in each of these areas.

Geological Schematic of Karst Profile (after Fletcher 2004)



Potential GI Problems



Notes:

1. Drillholes terminated on competent marble rock lens within a solution or collapse cavity infilled with a soil matrix, i.e. not founded on sufficiently load bearing ground.
2. Steeply dipping irregular rockhead makes defining DH termination depths and therefore founding level for bored piles difficult.
3. Cavity infill with possible voids below rockhead and base of bored pile, which may cause bearing capacity / settlement problems.
4. Folding in competent bedrock may result in weak or broken ground and require deeper piles.

Karst GI : Supervision

The involvement of an appropriately experienced and qualified engineering geologist to consult on the scope, sufficiency and findings of ground investigations (GI) is especially important for surface and sub-surface developments in the metasedimentary and marble-bearing rocks of Hong Kong. Rarely is the geological model and fullness of information more important in Hong Kong GI.

Useful Publications Specific to Karst in HK

Chan, YC (1994). Factors Affecting Sinkhole Formation (GEO Report No. 28). Geotechnical Engineering Office, Hong Kong.

Chan, YC (1994). Classification and Zoning of Marble Sites (GEO Report No. 29). Geotechnical Engineering Office, Hong Kong.

Chan, YC and Pun, WK (1994). Karst Morphology for Foundation Design (GEO Report No. 32). Geotechnical Engineering Office, Hong Kong.

Environment, Transport and Works Bureau Technical Circular (Works) No. 4/2004 – Checking of Foundation Works in the Scheduled Areas of Northwest New Territories and Ma On Shan and the Designated Area of Northshore Lantau.

Geotechnical Control Office (1990). Foundation Properties of Marble and Other Rocks in the Yuen Long – Tuen Mun Area (GCO Publication No. 2/90). Geotechnical Control Office, Hong Kong.

Karst Geology in Hong Kong. Geological Society of Hong Kong Bulletin No.4 (1990).

Chris N Fletcher (2004). Geology of Site Investigation Boreholes from Hong Kong. Published by AGS Hong Kong

Buildings Department Practice Notes: PNAP161

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