General Practice of Ground Investigation Works in Hong Kong Special Administrative Region

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Abstract: The future development in Hong Kong Special Administrative Region ("Hong Kong" in short to be used in this paper) requires reasonably large amount of ground investigation works. Ground investigation works in Hong Kong generally includes retrieving soil and rock core samples from the ground in order to obtain the sub-surface geological information for foundation design and slope study by means of drilling works, excavation of trial pit/trench and field/laboratory tests, etc. This paper has briefly outlined the general practice of ground investigation works carried out in Hong Kong from their preparation and design stages of ground investigation works, the use of drilling equipments and sampling tools, various field tests and their supervision by competent persons; eventually compilation of reports for use of the engineers. Of course, an account on safety issues relating to ground investigation works is also described. As a result of ground investigation work, plenty of the disused rock core samples may be re-used in the construction of pavement and carriageway, decoration material in parks or even shopping malls, rather than disposing them to landfill sites. With the hope of joint efforts of the government and developers to promote geo-science in our community by displaying the geological information and the samples recovered under their properties, the general public will be able to learn the local geology from them. Hong Kong will become a large geological museum naturally on the whole.

Introduction

Geological science is one of the elements through which the geological knowledge can be applied to engineering designs for the rapid urban developments. Geological engineering is the practical application of principles, concepts and techniques of the geological sciences to provide sustainable-engineered solutions to human needs.

Geologists in Hong Kong generally work in contracting firms, consultants and the government. They produce geological logs, geological maps and reports; build-up of geological

models; provide first-hand geological information for the subsequent geotechnical design by engineers. Due to the fast-paced urban development, there has been extensive sub-surface geological information obtained from ground investigation works mainly over the last 30 years. This information certainly is useful to the better understanding of the geological constraints and conditions in developing the areas concerned.

Prior to the development, such as the design of foundations for public housing, slope foundation, tunnels and bridges construction etc., ground investigation works to the construction sites are essential, which includes investigation by sinking drillholes, rock/soil slope investigation etc. In the scope of this paper, the general practice of ground investigation works for development of Hong Kong is described in details. The ground investigation procedures from the planning stage through the execution of ground investigation fieldwork, sampling tools, compilation of report, attention to environmental issues, safety concerns and environmental conservation are presented.

The retrieved geological information is very valuable and important for the design of urban developments. The disused rock core samples are also used for environmental purposes by re-using them in construction works.

Purpose of Ground Investigation

The purpose of ground investigation works for all types of developments in Hong Kong generally has similar goal to collect the underground information as much as possible and to build up geological models to facilitate the required designs.

Ground investigation works need to be carried out once the preliminary plan for a development has been endorsed. Ground investigation works are usually conducted at several stages namely: (a) feasibility study for ground condition by carrying out drilling of some boreholes; (b) detailed design by sinking more boreholes at locations of proposed structures of the development and conducting field and laboratory tests when its layout is available; and (c) sinking some more boreholes for confirmation of rock head level or soil properties as ground information for the engineer's design. At feasibility stage of ground investigation, boreholes are usually sunk over the entire site so that general geological information can be obtained for a preliminary ground assessment of the site. At this stage, there will be limited ground information available at the locations of the proposed structures. Following the next stage of ground investigation, drilling works are based on the designed layout plan and the boreholes are specifically located at the proposed structures to obtain the comprehensive ground information for the foundation/slope design. Last batch of boreholes are required to sink in the ground exactly at the pile/foundation locations or geotechnical structures in order to verify the ground conditions with respect to the foundation/slope design at the last stage of ground investigation works. In addition to sinking boreholes in ground investigation works, excavation of trial pits; trial trenches and slope stripping are also executed for loca-

ting the underground utilities (water pipes, sewerage pipes, electricity cables, telephone lines and gas pipes etc.), identifying if any adverse joint sets which may affect slope/foundation design. Surface stripping and drilling on slope surface help to retrieve sufficient sub-soil information for slope stability study too.

Planning Ground Investigation Works

Prior to the commencement of ground investigation fieldwork, a series of procedures have to be fulfilled. The engineer plans and designs the number and locations of boreholes, trial pits or slope stripping to be carried out on site. Site meetings with relevant parties, including the contractor's representatives, site inspectorate staff and land-owner representative, to apply/confirm site access and discuss the ways for carrying out ground investigation works smoothly as well as avoiding causing possible problems. A works order/instruction will be issued which stipulates all the requirements of the ground investigation works with a site layout plan. Setting out borehole locations is required on site as soon as instructions of ground investigation works are provided. Afterwards, contractor will mobilize drill rigs and equipments to the site and the drilling operation is ready.

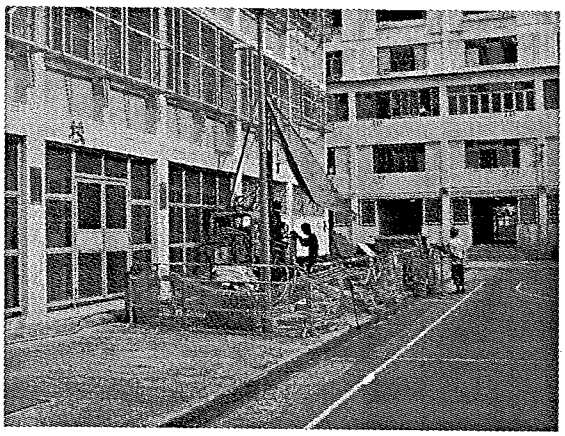

Fig. 1 General set up of works area for ground investigation

General drilling equipments include, but not limited to drill rig, drilling rods and casings, water tank for re-circulated water with silt removal facilities, electricity generator, portable site office (usually using metal container) and mobile toilet. Due to sunny weather of Hong Kong, the set up of a shading area above the drill rig using tarpaulin sheets or similar for the drillers is generally necessary.

Set up of Drilling Equipment

Ground investigation works will be carried out under different site circumstances:

(1) within an active construction site where site formation works are in progress and site access are obtained from the site formation contractor or relevant authorities; (2) within government land (under the control of Lands Department); (3) on public carriageway/footpath; (4) within private land lot.

Drill rigs and equipments are generally mobilized to site by crane lorry. However, the borehole locations may not always be convenient enough which are adjacent to an access road, they may be located miles up a squatter area where the access roads are narrow, as such the drill rigs and equipments need to be dismantled and carried manually through narrow access. In some cases, timber scaffolding is erected for the purpose of access and as working platform when ground investigation work is carried out on sites with difficult access. In some of the very remote site areas such as remote islands, mountainous terrain where transport of drill rigs and equipments are difficult, they are inevitably be transported by helicopter or other methods to the sites.

Sometimes, ground investigation works have to be carried out within uncovered car parks that are still in operation. Extra efforts were to be made to liaise with the car park owner for releasing available parking space at proposed borehole locations from time to time. However, through better communication and liaison, difficulty in completing the ground investigation works can be overcome generally.

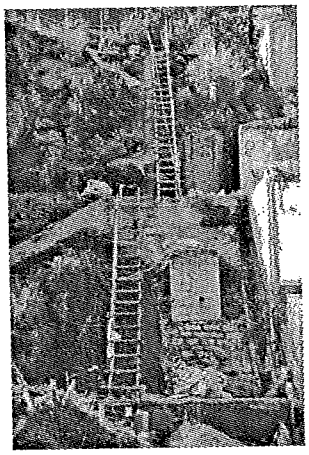

Fig. 2 Access for inspection of slope stripping

Fig. 3 Detection of underground utilities

In Hong Kong, excavation permits are required from the government for ground investigation works to be carried out on government land including public carriageway and footpaths. A set of regulations regarding safety and reinstatement requirements to the openings of ground needs to be followed strictly. There may be numerous underground utilities particularly in urban area including telephone lines, television cables, pressurized water pipes, sewerage pipes, high voltage electricity cables, and gas pipes etc. underneath a site. Therefore detection of underground utilities at the site is necessary before the actual execution of ground investigation works. It is useful to obtain updated utility plans from relevant utility

undertakers for reference before the commencement of any work. The general practice for detection of underground utilities in Hong Kong is to use geophysical techniques such as Radar detection instrument. Mobilization of drill rigs to borehole locations can then be arranged. Inspection pits are excavated manually at borehole locations to ensure that utilities are not located in their way of drilling and the maximum depth of this sort of excavation is generally 2m deep. Drilling work can then be proceeded according to the instructions.

In the past, there had been a few accidents in the industry involved with sinking boreholes which had hit the high voltage electricity cable (e. g. 13. 2 kV) and damaged a pressurized water pipe in the middle of carriageway. As a result, great loss from the damages was incurred.

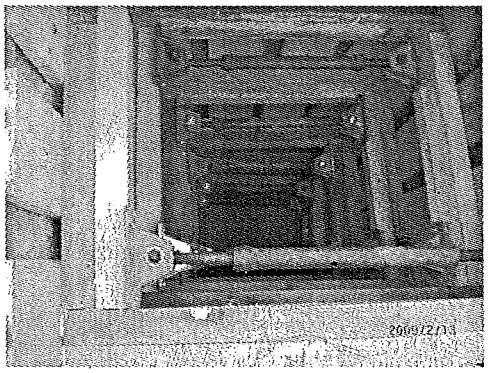

Fig. 4 Timber shoring for excavation of trial pit

Sometimes, trial pits/trial trenches will also be excavated manually for taking large undisturbed soil samples (block samples) and in-situ tests (sand replacement tests). The maximum depth of excavation is generally 3m with support of timber shoring.

Sampling and Field Tests

The choice of sampling methods in ground investigation works depends on the geological condition of the ground, the type of ground information to be obtained and the design criteria required by the engineer. Therefore the engineer will collect all relevant ground information of the site to obtain a preliminary perception of the ground conditions and resolve the existing or possible engineering problems that he may anticipate. The amount and types of ground investigation works required on the specific site may then be determined. Different ground investigation method will be adopted for different soil/rock types, for example: (1) marble terrain may be cavernous and attention must be drawn when a borehole is sunk, otherwise the drilling rods/casings may be lost if it encounters a large cavity; (2) recovering of cavity deposits requires certain sampling techniques by drillers; (3) triple-tube core barrel using foam as drilling medium (instead of water) may be ideal in sampling kaolin within a rock mass. In order not to lose the details of any portion of the recovered rock cores with very fractured rock or numerous kaolin-infill joints in boreholes for slope design, triple tube core barrel will be used which usually produces satisfactory results.

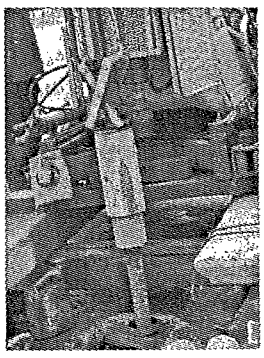

Fig. 5 SPT is in operation

Standard Penetration Test (SPT) is widely used as field

tests for ground investigation in boreholes for many years in Hong Kong. It is an assemblage of equipment composed of an automatic release trip hammer, drill rods, SPT sampler including a coupling, split barrel and driving shoe. When the sampler is placed in position at specified depth, the hammer (weighs 63.5 kg) will drop and hit the sampler into the ground. The number of blow count with respect to penetration is recorded for design reference. On the other hand, soil sample is recovered in an aluminium liner within the split barrel.

Fig. 6 SPT sample is recovered in liner protected by rubber caps

The sample collected in the liner is a disturbed sample and is usually used for the identification of soil types and fabrics by geologists. Correct test results marked on plastic sample jars containing the small disturbed samples from the driving shoe, liner samples etc. are also important so that the results of tests are consistent with the borehole logs. Previously, there have been a few research of improvement to the traditional SPT equipments carried out by some organizations. In future, SPT can be carried out in a more effective and convenient way unaffected by the inclement weather/possible human errors when the research results are fruitful.

Retractable Triple-Tube barrel is used to recover undisturbed soil samples from the in-situ ground. This sample is "Mazier sample". The sampler is lowered into the ground by hydraulic means. The soil sample recovered in the 1m plastic liner is sealed with molten wax at both ends and protected by rubber caps to keep moisture of the sample.

Details of the sample (such as contract no., works order no., borehole no., depth of sample and percentage of recovery etc.) are marked on the rubber caps as well as on the plastic liner for identification. The sample is placed in an upright position so that it may be kept in the same condition as it had been in the ground.

Fig. 7 The undisturbed samples are kept in upright position

Since the samples recovered are undisturbed samples, they are used for laboratory testing to assess the soil properties that can be adopted for geotechnical design. Sometimes, the samples are required to be split into 2-halves for inspection of soil textures and soil strata identification.

In case no recovery of soil is experienced in a retractable triple tube barrel probably due to the fact that soil is too cohesive or too sandy, a spring core catcher may be applied at the lower end of the sampler to improve recovery. However, this method may disturb the

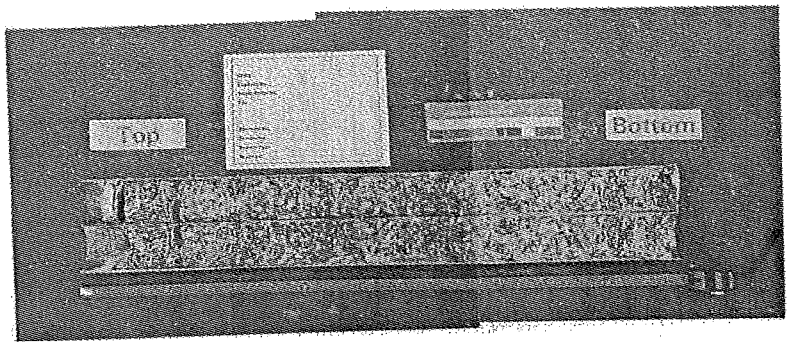

Fig. 8 Split undisturbed sample for inspection

integrity of the sample to some extent.

Rock core samples are normally recovered by double/triple tube core barrels in a borehole. The widely used double-tube core barrel has two sizes in Hong Kong, namely 101mm (T2) and 76mm (TN) internal diameter. Our general practice for coring rock samples is to use larger diameter core barrel at shallow depths. In this case, the smaller rock core barrel (TN) can be used to drill at greater depths in the borehole without the need of reaming the borehole when the T2 rock core barrel cannot proceed further into in the rock.

When some highly weathered/very fractured rock or colluvium are encountered, triple tube core barrel using foam as drilling medium may be required to collect as much sample as possible without being disturbed by the drilling water, such that the texture of the highly weathered rock or the matrix of colluvium can be preserved for detailed study.

The percentage of recovery by these rock core samplers in a core run represents the quality of rock in the ground and the contractor may determine the depth of termination of drilling in a borehole with the use of these data according to the instructions provided. The engineer may also select some representative rock cores for point load testing to verify the rock strength at particular depth of ground.

The recovered samples (disturbed small soil samples and rock cores) are carefully transferred to wooden core boxes. The details of every small-disturbed soil samples are marked on the plastic sample jars and depth indicators are given at both ends of rock cores. The samples containing in core boxes will be carefully studied, logged and photographed for the compilation of ground investigation reports.

For security reasons, the core boxes are chained, locked and kept in secure places temporarily on site. They are then delivered to the core stores for safety custody as soon as possible and kept in core stores until the completion of respective contracts. The core boxes of samples will then be disposed of at designated disposal ground (i. e. the public filling reception facilities) following the requirements of the government.

Fig. 9 Soil & rock samples are kept in wooden core box

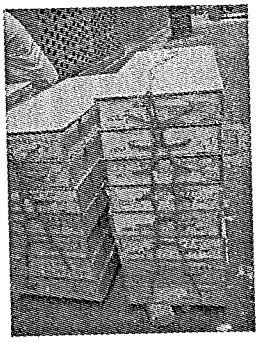

Fig. 10 Samples are kept safety in core boxes

Supervision of Works

Due to the rapid urban development of new commercial/residential buildings and major structures like new tunnels, bridges etc. and private/government housing redevelopment projects in Hong Kong, more ground investigation works are needed in the coming years. In order to maintain good standard of ground investigation works, the technically competent persons (works supervisors) will supervise ground investigation fieldwork according to the requirements of the government during the progress of ground investigation works. They are required to attain qualifications from institutions and assessed by the government authorities. All ground investigation fieldworks shall be supervised and endorsed in accordance with the requirements of the ground investigation contracts. Therefore, supervision of fieldwork is a very essential part of the ground investigation that proved the field tests as well as the soil and rock samples recovered from the ground are in accordance with the required work procedures.

Safety Issues

Where the ground investigation work sites are located in a street or on a slope, all work areas are fenced by barriers to secure the safety of the public. When ground investigation works are carried out within an active construction site, liaison with site formation contractor is essential on site safety issues especially when drilling work is near a blasting zone or along the haul roads of construction sites. Usually, induction safety briefings will be conducted in site office before any work commences in the site.

Sufficient barriers and traffic signs are required to separate the working areas and haul roads of construction sites so as to safeguard the workers from getting injured by construction plants/lorries. According to the regulations of the government, all moving parts of a drill rig and machinery shall be protected by metal safety guards. The exhaust fume pipe of

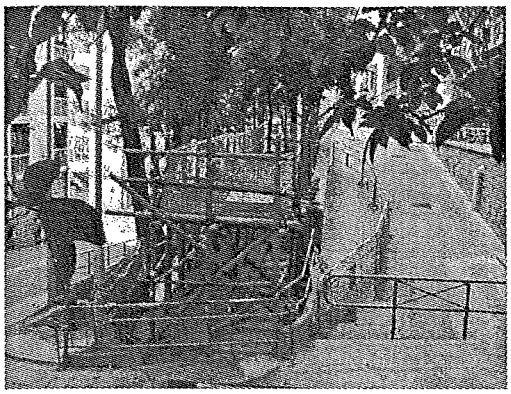

Fig. 11 Site safety set up for timber working platform

Fig. 12 Safety guard secures safety of drillers from moving parts of drill rig

drill rigs should generally be fixed at a level higher than the height of a driller; as such the driller shall not be injured by inhaling poisonous fumes.

Shades or shelters are required to be set up above the works area when the drillers are working under sunshine in high temperature. Guidelines should also be provided to the drilling crew whenever there are thunderstorms and lightning, they can keep themselves in safe places.

Sufficient drinking water is essential which shall be provided on site for the consumption of workers especially during very hot weather to prevent them from suffering heat stroke. For ground investigation works, crane lorries are usually deployed to mobilize drill rigs and machinery. Lifting heavy machinery and core boxes of samples require special attention due to the possible occurrence of industrial accidents. Banksman is therefore required to watch the traffic condtion in the vicinity of the crane lorry when it is under lifting operation.

Earplugs or ear mufflers, safety hard hats (safety helmets) and reflective jackets are the general personal safety equipment. Wearing a safety hard hat is a compulsory requirement of the government when one enters a construction site. The ears of the drillers are vulnerable to injury when they are consistently exposed to noisy environment at work; ear protection by wearing earplugs or mufflers is essential in order not to pose permanent damage to their ears.

On the other hand, the noise generated by the drill rigs should be reduced to minimum by taking every measure especially when the working sites are close to school, hospital, church etc. (They are the noise sensitive receptors). Besides, full body safety belts are required for workers working on scaffold platforms. Valid certificate of scaffold shall be issued by a competent person every two weeks which is required to be displayed at the scaffold after his inspection.

Since the outbreak of dengue fever (a type of mosquito decease) a few years ago, prevention measures for dengue fever has been implemented in construction sites by means of suppressing the rate of mosquito breeding through clearing the ponding water on depressed

ground, disused tires on site, bamboo ends etc. As such, the working site areas should be kept dry as far as possible. In addition, mosquito larvicide's spray is applied regularly at all working locations. Posters of prevention of mosquito breeding are put up at prominent locations of the working areas. Some guidelines are provided to workers such as wearing light coloured long sleeved clothes and to apply "mosquito-off" sprays. Not until early this year that the A/H1N1 influenza pandemic decease has been spread out worldwide. Some construction companies have prepared their own guidelines and request their employees for attention and report to their employers immediately for proper arrangement should they have contracted the disease.

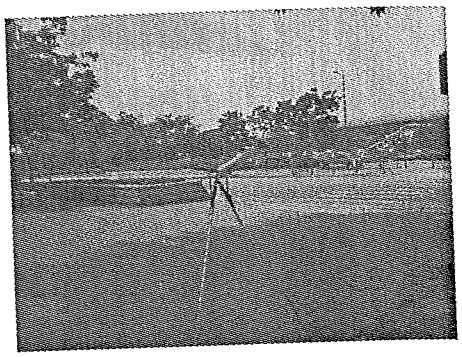

Fig. 13 Sound level meter

Environmental Compliance

Waste and garbage in bags or rubbish bins should be covered properly on site and disposed off the working sites regularly; water for drilling works should be recycled as far as possible and it should be treated through a de-silting water tank before discharging to the designated public drains. We need to take some careful measures to avoid polluting air when grouting borehole is in operation by setting up temporary facilities so that the quantity of fine particles suspending in the air due to grouting will be greatly reduced.

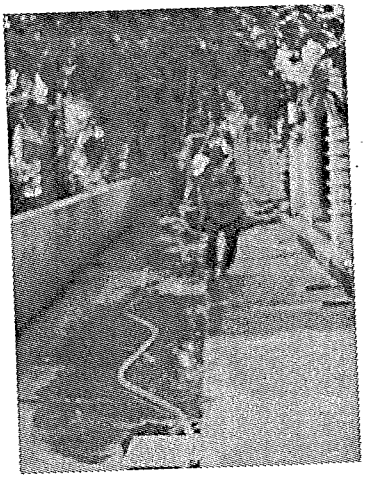

Fig. 14 Ponding water on depression of ground is cleared as far as possible

Nowadays, the construction industry has utilized sound level meter to measure the noise level generated from the ground investigation works. The noise level generated by ground investigation works will be under control.

All plants and equipments to be used on site shall be properly maintained in good operating condition and construction activities shall be effectively sound-reduced by means of silencers, mufflers, acoustic shields or screens to avoid disturbance to any nearby noise sensitive receivers (schools, hospitals etc.) or to carry out drilling works at particular time slots so as to avoid disturbing the neighbours. If the noise level exceeds the limits under the government regulations, ground investigation works have to be halted unless rectifications are taken.

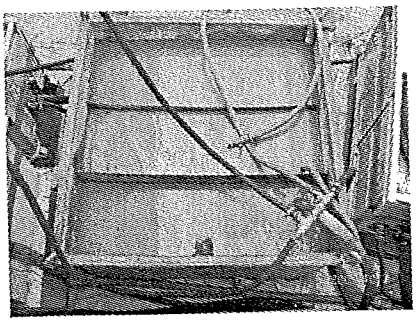

Fig. 15 Water-tank with silt removing facilities

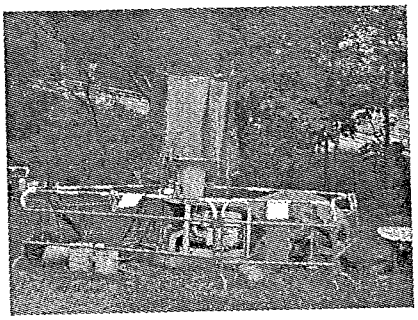

Fig. 16 Facilities to avoid cement particles from polluting the air during grouting

Borehole Logging and Ground Investigation Records

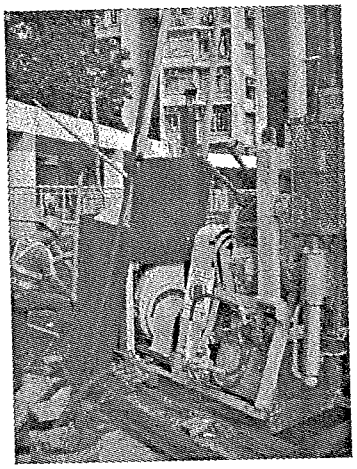

Fig. 17 Silencers/ acoustic shields

The soil and rock samples recovered from boreholes require careful handling and protected from being damaged for future reference and that these samples are logged by qualified geologists. The qualifications and experience of geologists are required to be assessed by the government authorities through examinations or have attained qualifications from tertiary institutions.

The borehole logs with photographs of the samples and field test results are compiled in ground investigation fieldwork reports, which are very important ground investigation information that the engineers use them as a basis for their foundation and slope designs. Geologists, who possess geological experience and professionalism, will sign on every ground investigation records, such as borehole logs, trial pit logs etc. since they are the competent persons for geological logging and responsible for the correctness of the borehole record. A borehole log should be an accurate and comprehensive record of the ground conditions. To achieve this requires both care and vigilance of the driller, logger and checker. An experienced geologist can always possess a 3-dimensional view in the ground and construct the geological history of a place as if he were the witness to the happening of the geological events in the past.

In Hong Kong, the logging practice is carried out with reference to Geoguide 3 "Guide to Rock and Soil Descriptions" published by the government. The results of borehole logs obtained from many construction sites logged by geologists in Hong Kong generally consist of the surface fill materials, alluvium/colluvium, some with marine deposits, sapprolitic material and the rock of various weathering grades including dykes and some geological structures occasionally. The description of the recovered samples in a borehole log consists of elements for engineers design, such as SPT "N-values'", degree of density of sand, stiffness of silt

and clay material as well as strength of rock cores etc.

In order to guarantee the quality and standard of the results of ground investigation works prepared by the Competent Person (logging) of contractors, checking the ground investigation records by experienced professional geologist of the client is recommended. It is understood that it has been the practice of qualified geologists of some government offices and consultants, who involve in ground investigation works, to check logging results of soil and rock samples so as to deliver reliable ground investigation information to the engineers. It is hoped that all government offices and consultants will deploy professional geologists to enhance the standard of logging samples from boreholes, trial pits, rock slopes etc. in the near future.

Recommendations for Environmental Conservation Through Ground Investigation

Many miles of rock cores retrieved from the ground will be disposed after the completion of projects. It will be considered as a waste of the Earth's resources as well as human resources, not to mention the waste of money for the ground investigation. After the collection of the disused rock cores by other government departments and universities for research/teaching purposes, we may make use of the disused rock cores for construction of pavement, as hard core for the road base of carriageway, planter in parks and housing estates or as decoration to shopping malls etc. There has been success of using disused rock cores for paving footpaths in other region of the world (e. g. Taiwan).

Fig. 18 Disused rock core paving for footpath - 1. (Hualien, Taiwan)

Hong Kong contains fascinating geological heritage, including dramatic landforms such as the red beds on Port Island, sedimentary formations in Ping Chau and jointed rock columns in High Island and Ninepin Islands. Apart from the existing landforms and the spectacular geological scenery of Hong Kong, it can become a city with geological knowledge at every corner of the housing estates, government/commercial buildings and even at street cor-

ners as education purpose. It can become unique in the world.

To do this, the government may encourage developers in Hong Kong to contribute a small area in their buildings/properties to display the geological information obtained right below the ground. The public can, in this way, share our experience and results of the geological findings, not only from the universities, Geological Society of Hong Kong – publications of the Civil Engineering Development Department (CEDD), etc., but also conveniently from shopping malls, office buildings, every public housing estates where geological models and information can be displayed right in front of the general public.

Fig. 19 Disused rock core paving for footpath – 2 (Hualien, Taiwan)

The display of geological information can be in the form of geological models at the lobby of a building, along the exposed rock surface of an access road of housing estate showing the geological section (e. g. granitic/volcanic rock of various weathering grades with rock joint patterns and geological structures of a dyke and fault displacement). The geological sections can also be displayed on the floor protected by clear floor tile material, thus they will not occupy too much space of the buildings.

Students of primary and secondary schools or universities may be able to examine the rock cores taken out from the ground where they are stepping on; they may also take reference to the illustration and geological models of the local geology and understand it more outside their classrooms. This can be considered as a huge geological museum of Hong Kong on the whole and would probably be the first region in the world that possesses display of local geology over the entire city.

In this manner, people are able to know the type of rock(s) lying below their home; if an ancient fault or dyke runs across the ground under the commercial centre, market or basket ball court; any underground cavities in marble rock under the foundation of their buildings and other geological structures beneath their homes. The virtual geology of Hong Kong can be unveiled in front of the people. People will know more about geology and their awareness in geology can promote preservation to our geological heritage successfully in long run. Hong Kong would be proud of itself as being the city/region in the world to possess such great innovation.

Summary

The content of this paper has briefly outlined the general practice of ground investigation works carried out in Hong Kong, which may be taken as a reference of ground investigation works for the fast-paced urban development in coming decade. As a result of ground investigation work, we may use the disused rock cores for construction of pavement, as hard

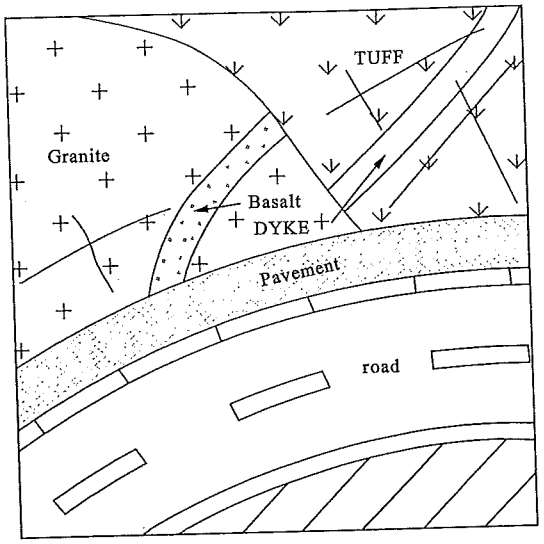

Fig. 20 Geological structures on rock exposure along a section of a road (schematic drawing by D. Yuen)

core for carriageway, decoration material in parks or even shopping malls. With the joint efforts of the government and developers by displaying the geological information and results obtained immediately below the developments, the geology under government/commercial buildings and housing estates will be unveiled in front of the general public and eventually it will promote preservation to our geological heritage in the future.

Acknowledgement

This paper is published with the permission of the Geological Society of Hong Kong Professional Branch. The author would like to thank Mr. S. K. Kwok for giving his valuable comments to the paper.

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香港特别行政区地质勘探工程的惯常做法

摘　要：香港特别行政区未来的发展极其需要大量的工程土地勘探。香港特别行政区(在本文中简称"香港")的土地勘探方式通常有开挖探井、探槽，提取土壤和岩芯样品，现场和实验室试验等，从以获得地表以及地表以下的地质资料作为地基设计和边坡安全的设计研究。本文简要地介绍了在香港进行的一般土地勘探的做法，包括从土地勘探的准备工作、设计的阶段、钻探设备和取样工具，以及必须有符合资格的人士监督各种现场试验和实验室试验；汇编最终钻孔记录报告，现场试验和实验室试验报告给工程师使用。当然，有关土地勘探工程安全的事宜，在本文也有描述。此外，在土地勘探工程完成后得到大量废弃的岩芯样品，本文也提议可以重新用来铺设行人道和行车道的路面，用作公园或商场内的装饰材料，而不是弃置它们于废物堆填区。希望政府和发展商的共同努力，可以展示给广大的市民看那些在发展物业下的地质资料和样品，从而让他们得到该地区更丰富的地质知识，促进在社区内市民对地球科学的认知，希望香港整体能成为一个大型的地质博物馆。