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The occurrence and classification of hard rock body in Putrajaya and its implication to construction activities

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Abstract: Putrajaya, the new federal administrative capital of Malaysia which is being designed as a paperless city, is still under construction. The geology of Putrajaya was reported as being underlain mainly by Hawthorden Schist and interbedded sandstone and shale of the Kenny Hill Formation with a localised granite body.
This paper discusses the occurrence of a very hard and abrasive rock body in Putrajaya. The name "Putrajaya Gneiss" is introduced for this rock body for discussion purposes for this paper based on preliminary study. Even though the distribution of this rock was only within a limited area, its occurrence was not expected, hence it created problems to the construction activities

INTRODUCTION

The construction of the new federal capital of Malaysia, Putrajaya, is still under way. To-date, the construction has moved to the second phase involving the construction of buildings and properties. The first phase of the construction, mainly the infrastructures, was completed at the end of the year 2000. One of the areas involved is Precint 2 where the major ministry offices will be placed.

This paper presents a discussion on the occurrence of a vary hard and abrasive rock body within the vicinity of Precint 2 that had created problems during construction activities i.e. during the course of excavation and foundation works. The name Putrajaya Gneiss was introduced herein for the purpose of discussion in this preliminary study.

GEOLOGY OF PUTRAJAYA

The overall study on the geology of Putrajaya was carried out by Chow *et al.*, (1994) prior to the construction of this new federal capital of Malaysia. Rock types found are Hawthorden Schist, sedimentary rocks of the Kenny Hill Formation and a granite body (Fig. 1). The oldest rocks are the schist, overlain by sedimentary rocks which consists of interbedded sandstone and shale. Intruding these two rocks is a coarse-grained megacrystic granite body.

Seventy five percent of the Putrajaya area is underlain by Hawthorden Schist. The schist occurred mainly as soil derived from *in situ* weathering. The thickness of residual soil (Grade VI) varies from 3 m to 8 m, while layers of completely to highly weathered schist (Grade V to IV) occurs approximately 12 m below ground level. Interbedded sandstone and shale cover approximately 10% of the area. The sedimentary rocks also occurred as soil, where the thickness of Grade VI material is approximately 6 m, while for Grade V to IV it is approximately 14 m. Alluvial deposits cover approximately 15% of the area, notably along Sg. Chua and Sg. Limau Manis. The alluvium consists of silty to sandy clay followed by fine to coarse sand. The thickness of the alluvium is approximately between 9 m and 10 m. In certain areas, however, the occurrence of hornfels and intrusive dykes were also reported (Soil Centralab Sdn Bhd, 1998).

BACKGROUND OF THE STUDY AREA

The site is located within the construction site for the office buildings and external works of government buildings, at Precint 2 (Fig. 2). Originally, the site was an undulating ground cultivated with oil palm trees. However, the elevation of the construction area was leveled at reduced level +39 m to +40 m (above mean sea level).

The site was then handed over to the successful bidder as a turnkey contractor. This turnkey contractor will develop this area on design-build-transfer basis. Under normal circumstances, all the bidders will have the opportunity to go through the conceptual design provided by the Consulting Engineers engaged by Putrajaya Corporation prior to submission of their tender. The design for the excavation and foundation works for the conceptual design were based on site investigation works carried out prior to the design stage.

The proposed building will consist of 2 towers with 10 storey and 3 basement levels. The platform level for the basement (base of excavation) is at reduced level +25 m (15 m below construction platform level).

DRILLING PROGRAM BEFORE AND DURING FOUNDATION WORKS

Sixteen boreholes were drilled before the commencement of excavation and foundation works, while 52 boreholes were drilled during the course of foundation works. Most of the 52 boreholes were drilled on or within

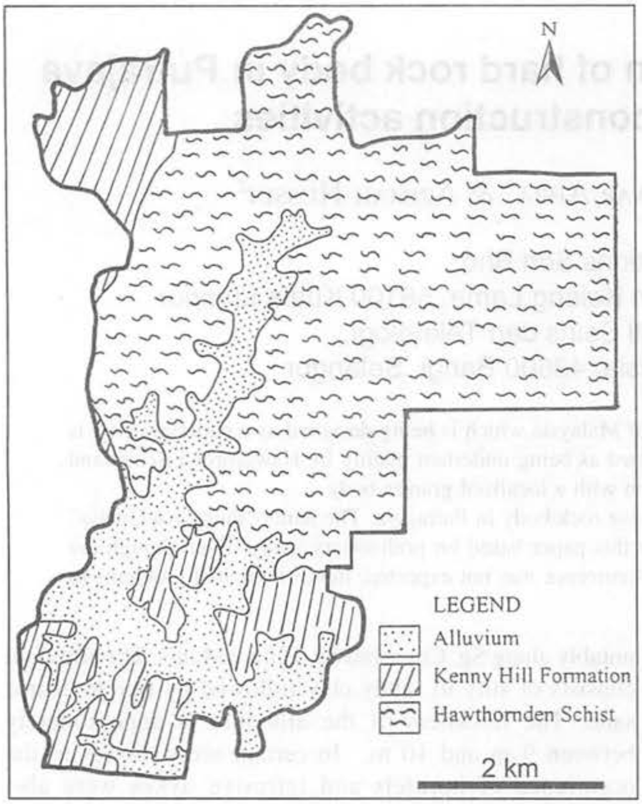

Figure 1. Simplified geological map of Putrajaya area (after Chow *et al.*, 1994).

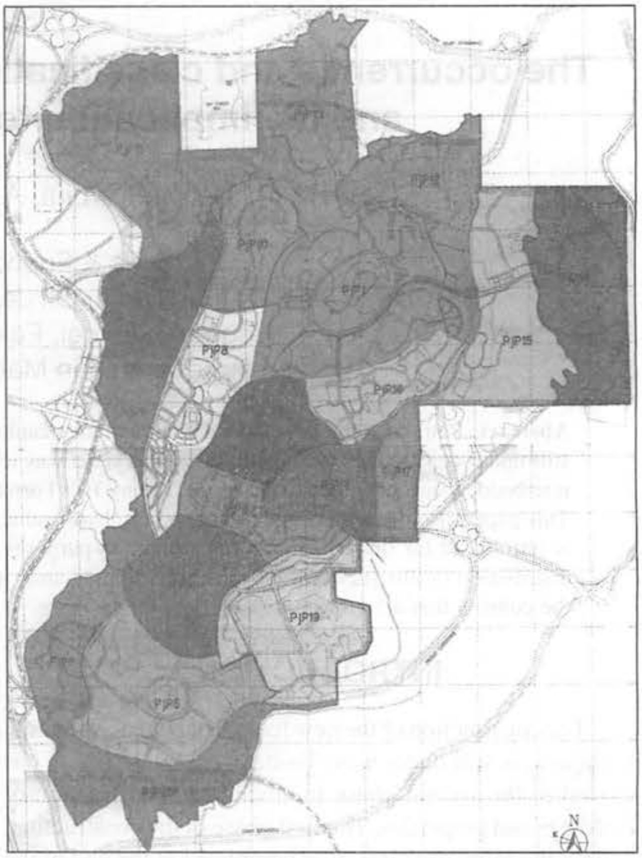

Figure 2. Precinct boundary plan of Putrajaya.

the pile cap points with the purpose of confirming the extent of the hard and abrasive rock body.

The drilling program was carried out by two different drilling companies, herein referred to as Company AB and XY.

In situ testing results such as Standard Penetration Test (SPT) showed variation due to differential weathering of the interbedded sandstone and shale, which reflect the variation in composition and structural pattern of the rocks.

Field description of rocks

Based on visual inspection by two geologists from two different drilling companies, the rock (Fig. 3) was identified as shale and schist, respectively.

The shale was described by geologist from Company AB as light grey to dark grey in colour, slightly weathered to fresh (Grade II to I). The rock strength was reported to be ranging from moderately weak to extremely strong.

The geologist from Company XY described the rock as schist with the strength ranging from strong to very strong. The rock is light to pale grey with streaked white in colour and slightly fractured. The weathering grade of the rock is slightly weathered to fresh (Grade II to I).

Petrographic examination

Due to suspicions on the field descriptions based on visual examination, three numbers of rock samples were sent for petrographic examination. The examinations were carried out by using a Zeiss petrographic microscope.

One of the samples was identified as arenite while the other two were identified as gneiss. All samples were chloritized and weakly sericitized. The chloritization was clearly visible especially under cross-polar. This type of alteration resulted in the decomposition of micas and other silicates (pyroxene and hornblende). Minor veins are dominantly filled by undulating quartz and chlorite.

Texturally, the gneiss is fine to medium grained. The gneiss consists of pyroxene, quartz, chlorite, sericite, apatite and opaque minerals (oxides). Pyroxene are present as subhedral columnar grains. The mica/clay contents of the samples are low. The relatively low mica/clay contents are presumably responsible for their high strength. Thus, the tendency of the rock to expand in the presence of moisture is negligible.

THE CLASSIFICATION OF PUTRAJAYA GNEISS

Limited data was collected for the purpose of this study due to certain restrictions during construction activities. Generally, the gneiss strikes 180° and dips 45° with the exposed thickness of 15 m.

Based on the drilling program results, the isopach map of the gneiss body was plotted (Fig. 4). The gneiss outcrops can be seen in Figures 5 and 6.

Figure 3. Rock core sample.

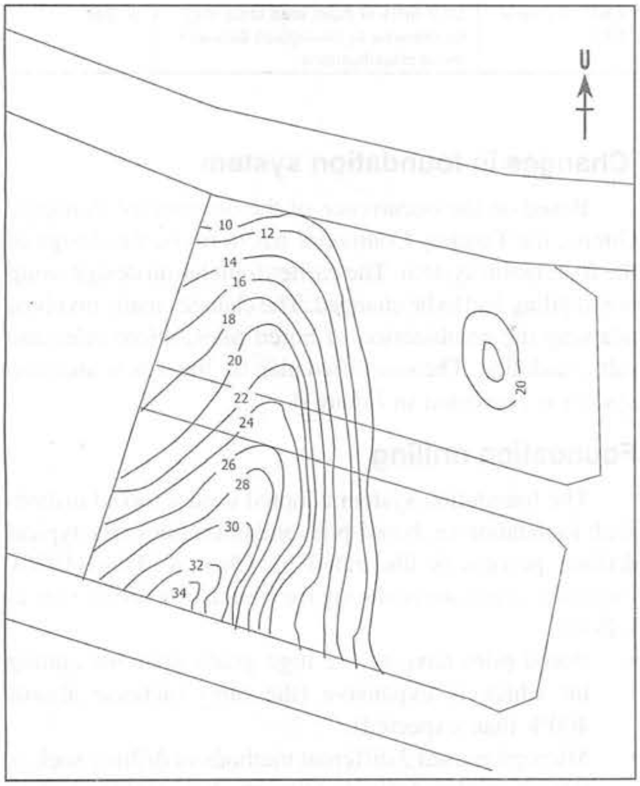

Figure 4. Isopach map of the Putrajaya gneiss.

The main classification criteria were recorded based on quick field observation, drilling and laboratory testing results. The parameters recorded were rock quality designation (RQD), discontinuities conditions, hardness and abrasiveness as well as rock strength.

Rock Quality Designation (RQD)

The Rock Quality Designation (RQD) index was introduced as an index of rock quality at a time when rock quality information was usually available only from geologists' descriptions and the percentage of core recovery (Deere & Deere, 1988).

RQD is used as a standard parameter in drill core logging and forms the basic parameters in two major Rock Mass Classification Systems; the RMR System and the Q-System (Barton *et al.*, 1974; Bieniawski, 1989).

Figure 5. Outcrop of the Putrajaya gneiss.

Figure 6. Closer view of the Putrajaya gneiss outcrop.

The Putrajaya Gneiss showed an increasing trend of RQD values over the rock depth. The first 1.5 m core length showed the range of 0% to 20%. The RQD value for the second and third core length range between 56% and 65% while for the fourth core length showed the RQD value is more than 86%. Total core run for each of the borehole was 6.0 m.

Discontinuities conditions

Conditions of the discontinuities were recorded based on visual examination as suggested by ISRM (Brown, 1981). Basically, the Putrajaya Gneiss has 3 sets of joints. The first set is dipping approximately 0° to 15°, closely spaced, smooth planar, extremely narrow, clay infilled and dry while the second set dips 40° to 50°, closely spaced, smooth undulating, extremely narrow, chlorite and iron stained infilled and dry. The third set dips 70° to 80°, medium spaced, smooth planar to rough undulating, extremely narrow, clay infilled and dry.

Rock hardness and abrasiveness

Hardness (Whitten & Brooks, 1972) is defined as a property of minerals in which is determined by reference to an empirical scale of standard minerals. Mineral hardness is based on 'scratch' (scelerometric) hardness, as opposed to the engineers' identification of hardness. For hardness, the Mohs' Scale is used.

Hardness is more readily and consistently described based on visual inspection and simple mechanical tests such as scratching with knife or striking with a hammer. Table 1 and Figure 7 (Heinz, 1994) indicates that there is a distinct correlation between rock strength, rock hardness and drillability for common rock types found in South Africa. The hardness of the Putrajaya Gneiss is estimated to be between 8 and 9 on Moh's scale.

Abrasion (Whitten & Brooks, 1972) is defined as reduction in size of rock particles by mechanical wearing-away, especially by the rubbing of two particles together. Abrasiveness (ADITC, 1996) can also effect the performance of drilling. Hard and tough rocks can also be abrasive. Abrasive materials can be difficult to drill not so much because they are abrasive, but because abrasive material (of necessity) is hard.

Abrasiveness is important due to its effect on bits and drilling system components. Abrasive materials cause increased wear of bits, pumps, seals and drill string surfaces. The harder and the sharper the grains, the less life you will have out of the bit you use. Such wear and tear increased the drilling costs. Based on the drilling performance, the Putrajaya Gneiss generally is less abrasive.

Strength

Unconfined Compressive Strength (UCS) test was carried out on some of the selected rock core specimens. The results showed that strength of the gneiss varies. This variation basically depending on the depth, bedding planes and the sampling locations. Comparisons of these results are presented in Table 2. The strength is reduced if rocks are tested at high angle to the bedding, flow or structural planes and if the specimens are wet. Results of the testing indicate that the strength of the Putrajaya Gneiss ranges from moderately weak to very strong.

IMPLICATION ON CONSTRUCTION ACTIVITIES

The turnkey contractor was having big problems to complete the foundation works as scheduled. The problems encountered are as follows:

Excavatability and blasting

Due to high strength of the Putrajaya Gneiss, the conventional excavation works were not possible. The rocks also cannot be ripped. Thus, the Turnkey Contractor had to blast the rock. The quantity and amount of the blasting works were increased beyond the original estimation.

Table 1. Classification of rock hardness (after Heinz, 1994).

Classification	Field Test	Approx. Range UCS, MPa
Very soft rock	Can be peeled with a knife, material crumbles under firm blows with the sharp end of a geological pick	1 to 3
Soft rock	Can just be scraped with a knife, indentations of 2 to 4 mm with firm blows of the pick point	3 to 10
Medium hard rock	Cannot be scraped or peeled with a knife, hand held specimen breaks with firm blows of the pick	10 to 25
Hard rock Very hard rock	Difficult to break hand held specimens. Classification based on experience with the rock type and its characteristics	25 to 70 70 to 200
Extremely hard rock	UCS tests or point load tests may be required to distinguish between these classifications	> 200

Changes in foundation system

Based on the occurrence of the unexpected Putrajaya Gneiss, the Turnkey Contractor has to revise the design of the foundation system. The earlier foundation design using bored piling had to be changed. The changes made involved adapting the combination of bored piles, micro piles and raft foundation. The simplified plan for the new foundation system is presented in Figure 8.

Foundation drilling

The foundation system adopted used a mixed drilled-shaft foundation i.e. bored-piles and micropiles. The typical drilling process is illustrated by Chan & Ting (1996). Problems encountered during the foundation drilling are as follows:

- Bored piles have to use high-grade diamond cutting bit which is expensive (the rates increase almost 400% than expected).
- Micropiles used 3 different methods of drilling such as top-percussive drilling, down-the-hole (DTH) drilling and overburden eccentric drilling system (ODEX). The top-percussive method was not working at all while the ODEX system was good but the system damaged easily and regular replacement was unaffordable. Commonly used method is DTH. However, the button bits and hammers used must be compatible with air pressure applied and the capability of the drilling rigs.
- Other problems were wear and tear of drilling rigs. Drilling and percussive parts were easily broken due to heat and high pressure applied. This is attributed to the hardness and the strength of the rock.

Overall progress and cost overrun

Owing to the above factors, the delay in overall progress

Table 2. Results of unconfined compressive strength (UCS) test of selected rock core samples.

Borehole No.	Sample No.	Reduced Level (m)	UCS (MPa)
1A	C1	26.0	133.7
2A	C1	21.6	13.2
3A	C1	15.5	108.1
	C1	14.85	120.6
	C2	12.5	66.7
4	C2	18.50	20
8	C2	8.70	13.4
	C2	8.30	20.6
9	C1	19.7	33.5
	C2	19	64.9
	C2	18	79.3
10	C1	25	39.8
	C2	23.5	157.8
	C2	22.6	76.6
11	C1	30.45	121.7
	C2	30.45	60.6
12	C1	33.05	64.1
	C1	31.70	126.2
	C2	30.50	80.1
C6	C1	4.55	35.94
	C2	3.47	56.05
	C3	2.33	81.52
F4	C1	6.054	24.33
	C2	5.104	17.92
	C3	3.904	81.26
H4	C1	3.713	43.61
	C2	3.163	24.69
	C3	1.443	31.94
H5	C1	7.8	17.32
	C2	7.3	17.99
	C3	6.3	20.17
L8	C1	21.712	44.25
F7	C1	22.307	121.6
	C2	20.307	119.8
F8	C1	22.797	32.6
	C2	21.297	67.9
	C3	20.297	71.8

is unavoidable and to make things worst the actual project budget definitely exceeds the preliminary budget. Hence the profit gained by the turnkey contractor is reduced.

DISCUSSION

The occurrence of gneiss was not highlighted during the site investigation program for conceptual design stage. The absence of rock classifications of gneiss in this area especially related to the strength, hardness and the abrasiveness of the rock is very significant. It showed the lack of geological or geomechanical inputs.

Probably the involvement of an experience geologist who can advise on the occurrence of such very strong and hard rock and its implication to excavation as well as the foundation works was limited or ignored.

The supervising or field geologists in Malaysia hardly send any suspicious or doubtful rock samples for petrographic examination for further clarification on the rock names or types.

Another aspect which is always lacking is the geomechanics classification of rock based on logging of rock core. Anon (1970) had suggested the description of Fracture State (FS) as part of rock classifications. The fracture state consists of Total Core Recovery (TCR, %), Solid Core Recovery (SCR, %) and Rock Quality Designation (RQD, %).

Bieniawski (1989) suggested the following parameter for geomechanics classification of rock masses or better known as Rock Mass Rating (RMR). The parameters are uniaxial compressive strength (UCS) of rock material, rock quality designation (RQD), discontinuities spacing,

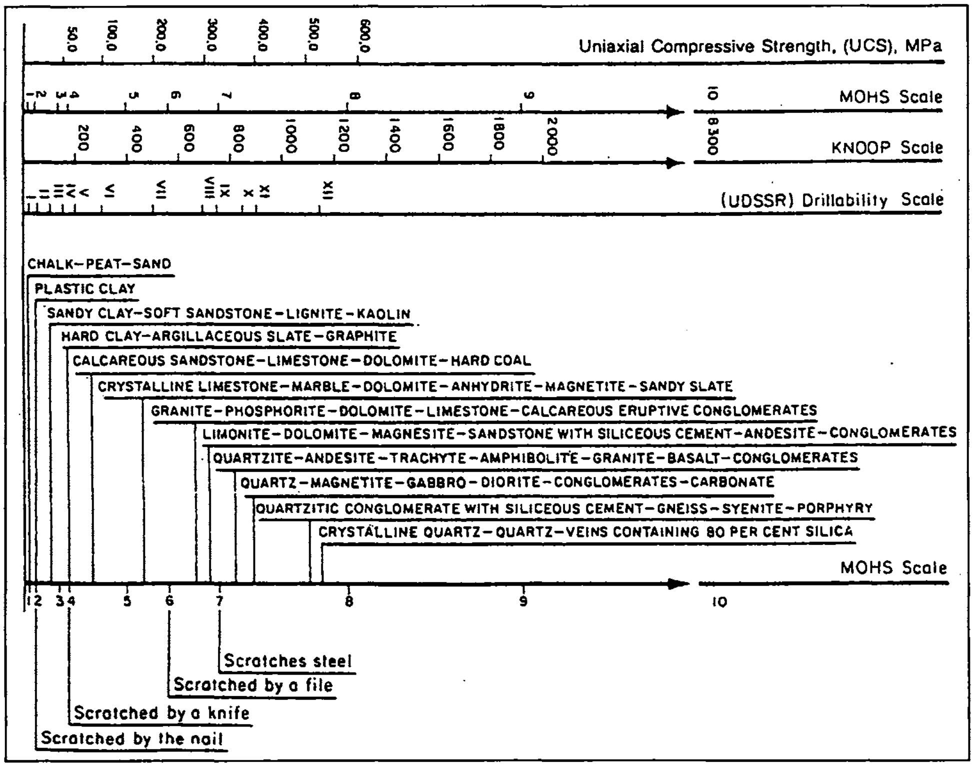

Figure 7. Rock strength and rock hardness chart (after Heinz, 1994).

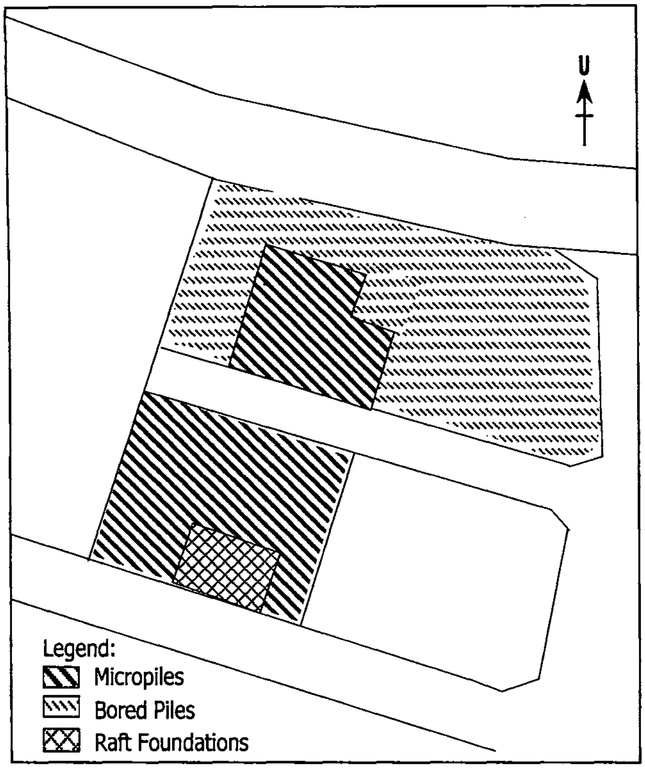

Figure 8. Simplified plan of revised foundation system.

discontinuities condition, groundwater condition and discontinuities orientation.

The important things to be highlighted here is that this geomechanics classification of rock mass can be carried out during the course of site investigation by an experience geologists. A discussion on this issue was well presented by Pettifer & Fookes (1994) on excavatibility assessment while Tajul & Mogana (2000) had presented local case studies.

CONCLUSIONS

The extent of gneiss was not established, logged and classified properly during the conceptual design site investigation program.

The identification of the rock should be carried out properly by the supervising geologists based on their training received. Should they not be confident, further consultation should be sought for from the expert or a petrographic examination should be made.

Any unusual features should be included in the report. Geologist should also put some extra effort in reporting issue related to engineering geology. Normally, the designer will appreciate any additional information that can assist them in the designing process.

Suitable drilling method and equipment for foundation drilling should be studied by the drilling expert.

In the summary of the preliminary investigation report by Geological Survey Department of Malaysia, a proposal was made on carrying out engineering geological mapping of excavated area during the construction stages. However, this proposal has never been followed for this specific site nor for other construction sites. The opportunity to update our geological information during the excavation and construction activities is always absent in the development agenda.

The purposes of investigation drilling as mentioned by Bieniawski (1989) are always not in the heart of some local geologists. Some of the purposes are:

- To confirm the geological interpretations
- To examine cores and boreholes to determine the quality and characteristics of the rock mass
- To study the groundwater conditions
- To provide cores for rock mechanics testing and petrographic analyses.

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