Engineering Characterisation of Kuala Lumpur Granite and Limestone

Haryati Awang and Norhanisah Abdul Karim

Abstract Rock properties are key elements that should be taken into account in designing substructures especially for underground structures such as tunnel and pile. For this reason, rock should be tested directly in the laboratory to measure the properties of the material particularly the physical and mechanical properties. This study is about investigating the quality of granite and limestone from Kuala Lumpur area for engineering purposes. As Kuala Lumpur is having a rapid development in urbanisation, construction in and on rock mass is an important element that cannot be avoided. Being part of tropical region, the quality of rock should be measured thoroughly because of deterioration and decaying of the material due to weathering. Referring to the problems encountered with rocks in tropical country, this study was carried out to characterise the engineering properties of granite and limestone found in the Kuala Lumpur area. Samples of granite and limestone were taken from a number of places where the borehole drilling for site investigation works is on progress. A finding of this study hopefully is useful in providing information of engineering properties of granite and limestone from Kuala Lumpur for technical communities.

Keywords Engineering properties · Granite · Limestone · Characterisation · Kuala Lumpur

1 Introduction

Rapid developments in capital of Malaysia, Kuala Lumpur, are encroaching the whole area of the city. Many of the engineering structures are built upon rock mass such as high rise buildings, railways and highways for transportation systems and tunnelling for raw water supply. Since, many substructures are constructed on rock

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masses; it is very essential to have a proper knowledge for technical communities who involve in the projects on the engineering properties of the material found in the structures in Kuala Lumpur.

Geologically, there are two main types of rocks that are mostly found in Kuala Lumpur which are granite and limestone. In Kuala Lumpur, about one third of the area is on limestone formation. The geologic setting of Kuala Lumpur and Ipoh (city in the state of Perak) is strikingly similar where the granite intruded the sedimentary formation of limestone [1]. The limestone is dominantly found at the centre of Kuala Lumpur city meanwhile, granite mostly bounded at the eastern area of Kuala Lumpur towards the Main Range of Peninsular Malaysia. The design and construction in limestone area have various problems to geotechnical engineers due to karstic features of limestone such as steeply inclined bedrock, cavities, slump zones and sink holes. The construction problem is mostly due to piling works.

Granite is the rock that is considered as having a massive structure, and is often assumed as stable and suitable for any construction projects. In Malaysia, incident of rock slides may have happened several times in the past but they were not too obvious as the Bukit Lanjan rock slide which blocked the nearby highway and caused the closure for 6 months [2]. The problem faced by granitic rock is when it is exposed to weathering that causes rock material to decay and deteriorate. Slopes and terrains are the most risky area for granite formation. Examples of such failure include the highland Tower tragedy in 1993, rockslide at Bukit Lanjan in 2003 and landslide at Bukit Antarabangsa in 2008. All these cases involve construction on granite on hill slopes.

This research was carried out to provide information on engineering properties and characteristics of Kuala Lumpur granite and limestone. This research study was conducted based on the ongoing highway project connecting Sungai Besi to Ulu Kelang in Kuala Lumpur city. The main objective of this research work is to determine the physical and geological properties of limestone and granite through a series of testing conducted on the rock samples. The findings from this laboratory testing will be used to determine the physical and mechanical properties of limestone and granite; and to characterise the geology of limestone and granite by petrography study. The engineering characterisation of rocks from Kuala Lumpur significantly provides information to the geotechnical practitioners, rock mechanics society and engineering geology communities on this natural material from a place in tropical region.

2 Materials and Methods

The rock samples for this study were provided by a site investigation contractor who is responsible to report the result of engineering properties from Kuala Lumpur area to the consultant of the project (Fig. 1). All laboratory tests were conducted in Universiti Teknologi MARA Rock Mechanics Laboratory. A total of 64 numbers of

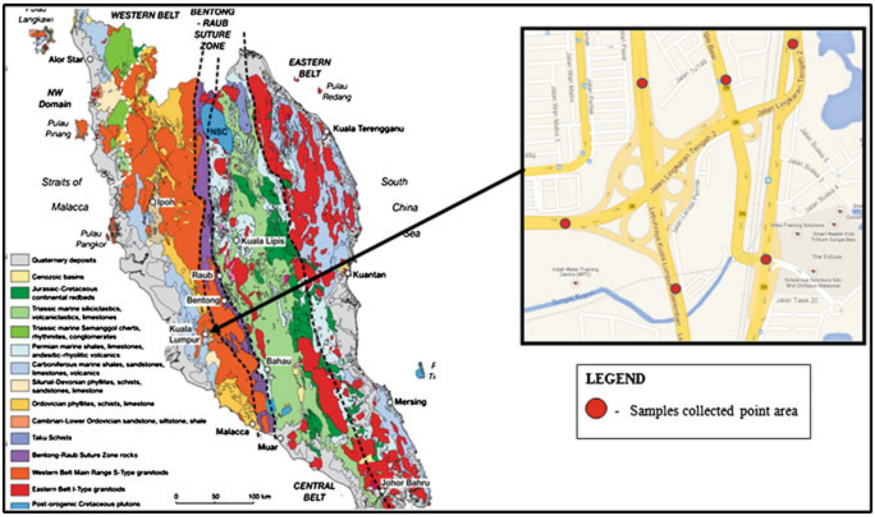


Fig. 1 Samples from borehole locations

rock samples from 32 boreholes were collected during site investigation works using borehole drilling method. The tests were referred to the Standard of Rock Characterisation Testing from International Society of Rock Mechanics manual (ISRM) [3]. In this research, there were five laboratory tests that were conducted to measure the engineering parameters of granite and limestone rock materials. The tests were divided into two groups which are the determination of physical and mechanical properties of rock. Physical properties identification was done by petrography description while determination on mechanical properties was conducted by several tests including uniaxial compression strength (UCS), point load test (PLT), Brazilian test and slake durability test.

3 Result and Analysis

Upon completing the laboratory tests, results were recorded and classified based on the types of tests.

3.1 Uniaxial Compressive Strength (UCS)

The uniaxial compression test is the main test in the laboratory for the rock samples. This is a destructive test that was performed on cylindrical rock specimen by compressing or loading them to get the maximum load to fail. Upon failure, the rock specimen usually fractures by axial, brittle splitting or fails in shear, depending on the specimens affected by the platens of testing machine and the surface quality of the particle, Tables 1 and 2 indicate the results for granite and limestone of UCS.

Table 1 Result of UCS for granite

Sample	Diameter (mm)	Height (mm)	Weight (g)	Area (m^2)	Max load (kN)	UCS (Mpa)
P513	51.88	103.76	560.4	0.00211	140.993	66.69
P514	51.89	103.78	562.9	0.00212	113.313	53.58
P515	51.59	103.18	557.0	0.00209	106.15	50.77
P516	51.75	103.50	566.9	0.00210	134.847	64.10
P517	51.25	102.50	565.2	0.00206	120.952	58.62
P518	51.47	102.94	552.1	0.00208	136.986	65.83
P519	51.83	103.66	555.8	0.00211	89.9760	42.64
P521	51.6	103.20	571.7	0.00209	137.638	65.23
P522	51.11	102.22	557.9	0.00205	131.775	61.78
P523	51.80	103.60	563.7	0.00211	40.2110	19.55
P524	51.68	103.36	547.4	0.00210	33.4790	15.96
P525	51.75	103.50	552.0	0.00210	193.670	92.07
P526	52.08	104.16	566.0	0.00213	93.5590	43.91
P527	51.89	103.78	566.5	0.00212	82.0630	38.80
P528	51.70	103.40	552.3	0.00210	160.628	76.51
STN13/1	52.01	104.02	534.4	0.00212	220.664	103.85
STN13/2	51.89	103.78	566.5	0.00212	89.3580	42.33
P483	52.24	104.48	588.3	0.00214	135.782	63.34
P484	52.19	104.38	605.1	0.00214	70.4180	32.91
P485	51.75	103.50	551.2	0.00210	111.760	53.13
P486	52.20	104.40	565.8	0.00214	67.1150	31.38
P487	52.31	104.62	602.8	0.00215	41.3740	19.25
P482	52.29	104.58	588.7	0.00215	97.4030	45.35
P481	51.93	103.86	564.9	0.00212	73.1790	34.55
P479	52.07	104.14	586.1	0.00213	104.142	48.90
P480	51.97	103.94	584.0	0.00212	115.703	54.54
P478	52.05	104.10	592.9	0.00213	80.6290	37.89
P477	51.63	103.26	563.3	0.00209	77.206	36.87
P476	47.41	94.82	436.7	0.00177	65.905	37.33
P475	51.66	103.32	545.6	0.00210	55.985	26.71
P473	51.77	103.54	596.5	0.00211	72.791	34.58
P465	51.49	102.98	579.7	0.00208	80.42	38.62
P490	52.07	104.14	533.7	0.00213	19.044	38.11
P502	51.88	103.76	568.5	0.00211	15.268	24.55

Table 2 The result of UCS for limestone

Sample	Diameter (mm)	Height (mm)	Weight (g)	Area (m^2)	Max load (kN)	UCS (Mpa)
P421	51.88	103.76	578.0	0.00211420	63.151	29.87
P425	53.30	106.60	630.4	0.00223152	26.540	11.89
P426	53.40	106.80	601.2	0.00223990	13.370	5.97
P427	53.50	107.00	627.4	0.00224830	21.151	9.41
P428	51.73	103.46	558.4	0.00210199	120.496	57.32
P429	52.04	104.08	615.5	0.00212726	195.246	91.78
P430	52.20	104.40	596.9	0.00214036	62.883	29.38
P431	51.74	103.48	555.3	0.00210281	13.554	6.45
P432	53.80	107.60	598.7	0.00227358	63.849	27.92
P433	52.78	105.56	592.9	0.00218819	98.168	44.86
P434	52.05	104.10	602.9	0.00212808	167.323	78.63
P435	51.58	103.16	609.0	0.00208982	148.687	70.41
P436	52.94	105.88	623.1	0.00220148	116.193	52.78
P437	51.65	103.30	574.4	0.00209550	8.852	4.21
P438	52.86	105.72	623.2	0.00219483	111.649	50.87
P439	53.24	106.48	600.4	0.00222650	95.977	43.11
P440	51.60	103.20	609.1	0.00209144	183.798	87.88
P441	52.90	105.80	600.1	0.00219815	103.988	47.31
P442	51.77	103.54	614.6	0.00210524	73.114	34.73
STN 11/1	51.53	103.06	555.9	0.00208577	47.626	22.83
STN 11/2	51.88	103.76	593.2	0.00211420	120.909	57.19
P443	51.75	103.5	544.2	0.00210362	110.007	52.29
P415L	51.62	103.24	574.8	0.00209306	8.723	4.17
P415R	51.64	103.28	583.9	0.00209468	62.041	29.62
P416	51.51	103.02	591.9	0.00208415	104.787	50.28
P449	52.16	104.32	585.7	0.00213708	49.466	23.15
P418	51.71	103.42	577.7	0.00210037	88.339	42.06
P414L	51.28	102.56	581.2	0.00206558	42.081	20.37

3.2 *Point Load Strength*

Point load test is another simple index test for rock material. It gives the standard point load index, Is(50) that was calculated from the point load at failure and the size of the specimen, with size correction to an equivalent core diameter of 50 mm. The result is tabulated in Tables 3 and 4 for granite and limestone, respectively.

Table 3 Results of point load for granite

Sample	*D* (mm)	*H* (mm)	Wt (g)	Force, *P* (kN)	Equivalent diameter, De^2 (mm)	Point load strength index, is (MPa)	Correlation factor, *F*	Point load index is (50) (MPa)
S1G	51.92	51.06	284.7	26.71	3375.40	7.91	1.07	8.46
S2G	52.07	51.96	284.4	9.93	3444.82	2.88	1.07	3.08
S3G	51.97	51.32	297.5	16.682	3391.94	4.92	1.07	5.26
S4G	52.10	51.84	285.7	10.43	3438.85	3.03	1.07	3.24
S5G	51.35	51.29	286.3	19.285	3353.58	5.75	1.07	6.15
S6G	52.31	52.28	294.6	17.361	3482.01	4.99	1.08	5.39

D Diameter; *H* Height; *Wt* Weight

Table 4 Results of point load for limestone

Sample	*D* (mm)	*H* (mm)	Wt (g)	Force, *P* (kN)	Equivalent diameter, De^2 (mm)	Point load strength index, is (MPa)	Correlation factor, *F*	Point load index is (50) (MPa)
S1	51.91	50.02	284.7	11.244	3374.97	7.91	1.07	8.46
S2	51.85	52.3	317	7.96	3452.27	2.31	1.08	2.49
S3	52.45	52.28	275.2	1.834	3491.33	0.53	1.08	0.57
S4	51.9	51.4	309.7	1.916	3396.57	0.56	1.07	0.6
S5	51.96	52.03	314.3	8.608	3441.51	2.5	1.07	2.68
S6	51.29	51.14	289.9	6.186	3340.32	1.85	1.07	1.98

D Diameter; *H* Height; *Wt* Weight

3.3 Tensile Strength

Brazilian test is interpreted as indirect method to determine the tensile strength of the rock. The test is to measure the weakest point of rock specimen due to tensile load. Result of tests is Tabulated in Tables 5 and 6. The tensile strength of the rock

Table 5 Result for Brazilian test of granite

Sample	Diameter (mm)	Thickness (mm)	Weight (g)	Max load, *P* (kN)	Tensile strength (MPa)
S1G	47.48	23.7	111.4	16.473	9.31
S2G	52.29	25.9	136.8	17.912	8.41
S3G	52.2	26.5	134.5	5.227	2.4
S4G	52.04	26.3	148.5	31.653	14.7
S5G	51.78	25.08	141.2	8.646	4.23
S6G	51.97	25.5	125.6	8.776	4.21

Table 6 Result for Brazilian test of limestone

Sample	Diameter (mm)	Thickness (mm)	Weight (g)	Max Load, P (kN)	Tensile strength (MPa)
8					
S1	51.75	25.87	149.4	11.76	5.59
S2	52.44	26.22	150	12.88	5.96
S3	51.93	25.96	157.3	5.798	2.74
S4	51.75	25.88	163.2	5.483	2.6
S5	51.88	25.94	145.6	22.286	10.53
S6	51.95	25.97	155.4	21.65	10.21
S7	51.98	25.99	148.4	20.493	9.65

is calculated from failure load (*P*), specimen diameter (*D*) and specimen thickness (*t*) by the following formula:

$$\text{Tensile strength} = \frac{0.636P\,(100)}{Dt} \tag{1}$$

where

P Load of failure (N)
D Diameter of specimen (mm)
t Thickness of specimen (mm)

3.4 *Slake Durability*

The slaking process involves two groups of different rocks which are granite and limestone. The purpose is to measure the differences in durability between granite and limestone from the same place of taking. Table 7 shows the slake durability index of granite and limestone throughout the slake process.

Table 7 Slake durability of granite and limestone

Sample	Empty drum mass (g)	Sample and drum mass (g)	Dried sample and drum mass (g)	Slake durability cycle				Slake durability index	
				Cycle 1 (g)	Cycle 2 (g)	Cycle 3 (g)	Cycle 4 (g)	Id_1 (%)	Id_2 (%)
Limestone	1801.45	2249.37	2247.33	2242.12	2239	2237.16	2235.17	98.74	98.04
Granite	1791.33	2298	2196.15	2285.17	2278.24	2273.03	2138.6	97.82	96.45

3.5 Petrographic Analysis

3.5.1 Granite

The mineral in thin section are seen by Plan Achro FP 10X/0.25. In granite, feldspars and quartz are major constituent minerals. Feldspars can be divided into two types which are alkali feldspars and plagioclase feldspars that consist of 25 % of mineral constituent, respectively. Alkali feldspars are more common than plagioclase, because they are more resistant to chemical weathering. Simple twinning as seen in Fig. 2 is very common in monoclinic alkali feldspar and this serves to distinguish them from plagioclases since the latter usually shows lamellar twinning as well as simple twinning.

Quartz is also the most abundant grain in granite with 40 % mineral constitution. The matrix between the quartz and feldspar grains contains dark minerals such as biotite, olivine or hornblende commonly present in granite constitute 10 % of the thin section specimen of granite.

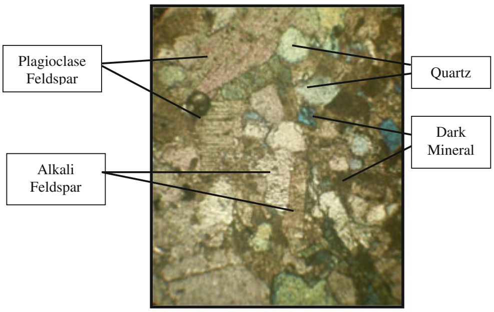
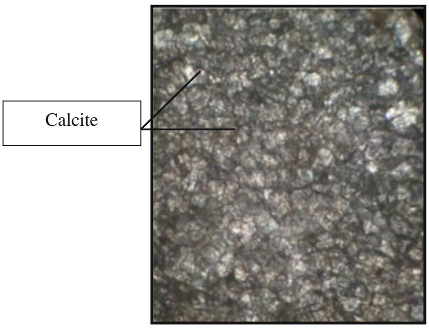
Type of Rock	**Mineral composition (%)**
Granite  	i. Feldspar - Alkali feldspar 25% - Plagioclase Feldspar 25% ii. Quartz 40% iii. Dark mineral 10%
Limestone  	i. Calcite 100%

Fig. 2 Microscopic image of granite and limestone

3.5.2 Limestone

Calcite cement is usually fairly coarse grained and constitutes 100 % in the limestone rock as it is originated from calcium carbonate mineral based such as shell brachiopod. Occasionally they are so coarse resulting in a poikilitic texture. Figure 2 shows sandstone in which the detrital grains are subangular to surrounded quartz. The cement is calcite of such a grain size that there are only a few crystals in the field of view shown.

4 Discussions

Based on the result of the engineering properties for granite and limestone of this study, there are two types of characteristics which are physical and mechanical characteristic. For mechanical characteristic, four types of tests have been conducted which are UCS, point load test, Brazilian test and slake durability test. The value that obtained from UCS is 15.96–103.85 MPa for granite and 4.17–87.88 MPa for limestone. Then for the point load test, the value for the granite is 3.0–8.5 MPa and for the limestone is 0.5–8.5 MPa. For the third test which is Brazilian test, the result was 2.4–9.4 MPa for granite while 2.6–10.6 MPa for limestone. The result for slake durability test is indicating in percentage which is different from other test. The result

Table 8 Summary of engineering characterisation of granite and limestone of Kuala Lumpur

<table>
<tr><th></th><th>Engineering properties</th><th colspan="2">Granite</th><th colspan="2">Limestone</th><th colspan="2">Rock quality compared to standard value</th></tr>
<tr><td rowspan="8">Mechanical characteristic</td><td rowspan="3">Unaxial compression strength (MPa)</td><td colspan="2" rowspan="3">15.96–103.85</td><td colspan="2" rowspan="3">4.17–87.88</td><td>Granite</td><td>Limestone</td></tr>
<tr><td colspan="2">Bieniawski [4]</td></tr>
<tr><td>Vey low–high strength</td><td>Vey low–high strength</td></tr>
<tr><td rowspan="2">Point load index (MPa)</td><td colspan="2" rowspan="2">3.0–8.5</td><td colspan="2" rowspan="2">0.5–8.5</td><td colspan="2">Bieniawski [4]</td></tr>
<tr><td>Medium–high strength</td><td>Very low–high strength</td></tr>
<tr><td>Tensile strength (MPa)</td><td colspan="2">2.4–9.4</td><td colspan="2">2.6–10.6</td><td colspan="2">–</td></tr>
<tr><td rowspan="2">Slake durability (%)</td><td colspan="2" rowspan="2">98.0–99.0</td><td colspan="2" rowspan="2">96.4–97.9</td><td colspan="2">Hasani and Scoble [5]</td></tr>
<tr><td>High quality</td><td>High quality</td></tr>
<tr><td rowspan="5">Physical characteristic</td><td rowspan="5">Petrographic description (mineral composition)</td><td>Mineral</td><td>%</td><td>Mineral</td><td>%</td><td rowspan="5">–</td><td rowspan="5">–</td></tr>
<tr><td>Feldspar (Alkali)</td><td>25</td><td rowspan="4">Calcite</td><td rowspan="4">100</td></tr>
<tr><td>Feldspar (Plagioclase)</td><td>25</td></tr>
<tr><td>Quartz</td><td>40</td></tr>
<tr><td>ark mineral</td><td>10</td></tr>
</table>

is 98.0–99.0 % for granite and 96.4–97.9 % for limestone. The physical characteristic test was conducted by petrography study. The mineral content found in granite are feldspar, quartz and a little of dark minerals. The percentage of each mineral is different due to the origin of granite during crystallisation and cooling process. Calcite was only mineral found in limestone sample in the study. The summary of the engineering characterisation of granite and limestone from Kuala Lumpur is shown in Table 8.

The results were compared with the established value of each strength categories to remark the quality of the rock [4, 5].

5 Conclusions

It can be concluded that this study has provided significant information of the engineering characterisation for granite and limestone from Kuala Lumpur. The strength quality of UCS for granite and limestone varies from very low to high strength, meanwhile for point load index, the quality is from medium to high strength and very low to high strength for granite and limestone, respectively. The wide range of strength quality is may be caused by weathering and dissolution of both the types of rock. However, most of the samples have high durability index.

References

1. Hutchison, C.S., Tan, D.N.K. (Eds.). (2009). Geology of Peninsular Malaysia, University of Malaya/Geological Society of Malaysia, Kuala Lumpur.
2. Gue, S.S. & Cheah, S.W. (2008), "Geotechnical Challenges in Slope Engineering of Infrastructures", International Conferences on Infrastructures Development, Putrajaya Mariott Hotel, 7–9May 2008.
3. Rock Characterization, Testing and Monitoring, ISRM Suggested Methods, ed. E.T. Brown, Pergamon, Oxford, (1985)
4. Bieniawski, Z. T. (1975), The point load test in Geotechnical Practice. *Engineering Geology 9*, 1–11.
5. Hassani, F.P., Scoble, M.J. & Whittaker, B.N. 1980. Application of slake durability index test to strength determination of rock and proposals for new size-correction chart. *Proc. 21st U.S. Symp. Rock Mechanics, Rolla*, Md.:.543–564.