

Karstic Features of Kuala Lumpur Limestone

TAN Siow Meng, Simon, Committee Member, Geotechnical Engineering Technical Division

1. Introduction

Kuala Lumpur Limestone is well known for its highly erratic karstic features. With the exception of Batu Caves, exposures of Kuala Lumpur Limestone are mainly found in tin mining areas. Such exposures seldom exist today after the closure of the tin mines. Ex-tin mining lands are covered with remnants of highly heterogeneous nature from slime to sand.

If the underlying karstic limestone bedrock is overlooked or not dealt with appropriately, it will pose great uncertainties and difficulties in foundation construction. In less fortunate cases, adjacent properties are affected or buildings suffer damages or failures after completion.

2. Geology of Kuala Lumpur Area

Published geological maps of Kuala Lumpur area show that Kuala Lumpur Limestone Formation dominates the majority area of KL. A geological section through KL is shown in Fig. 1. The limestone is estimated to be about 1,850m thick, overlying graphitic schist known as Hawthornden Schist. The top of the sequence is Kenny Hill formation which occupies the heartland of KL including areas at KLCC and Bukit Bintang.

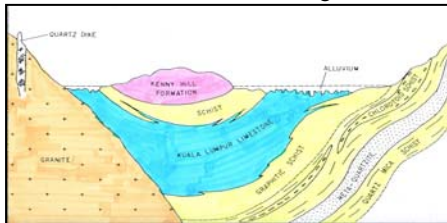


Fig. 1 Geological section through Kuala Lumpur (Yeap 1986).

According to Gobbett & Hutchison (1973), Kuala Lumpur Limestone is "Upper Silurian marble, finely crystalline grey to cream, thickly bedded, variably dolomitic rock. Banded marble, saccharoidal dolomite, and pure calcitic limestone also occur"

3. Tin Mining Activities

Tin mining activities in Kuala Lumpur started in 1857 when the first mine was operated in Ampang. Tin mining was rampant in the past and concentrated in the limestone area of Kuala Lumpur as shown in Fig. 2. Note that most information concerning the tin mining industry of Selangor before the Second World War was lost or destroyed during the war (Yin 1986), and as a result, it has not been possible to have a complete and accurate record of all the mining areas.

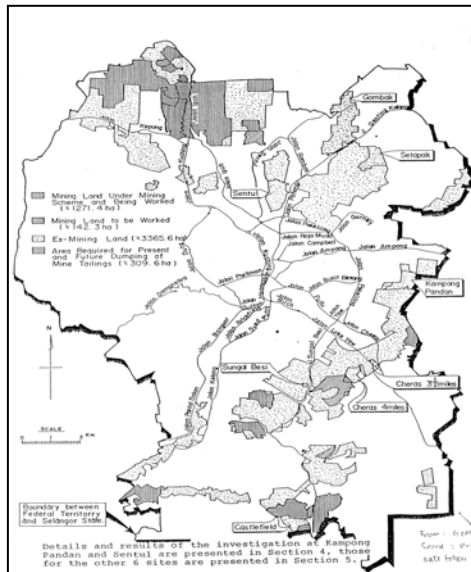


Fig. 2 Ex-tin mining area in Kuala Lumpur (GSM unpublished)

Most tin mine tenures expired in the early 80s. The common mining method was open cast and gravel pump. This method involved excavation by big machines such as bucket wheels and 'navies'. At confined places, such as potholes and pinnacles, the sediments were first broken by water jet and washed down to a pool which was then pumped to flow down along a sluice built on a tall wooden framework called 'palong' (Fig. 3), thus concentrating the heavy minerals including the tin ore cassiterite (Ayob 1965).



Fig. 3 Palong in an opencast tin mine in Segambut (Gobbett, 1973)

The mining activities left behind numerous ponds and remnants mainly consisting of sand and clay slime, forming a highly heterogeneous overburden materials over the limestone as illustrated in Fig. 4.

4. Karstic Features

4.1 Development of Karsts

Karst topography in limestone is formed by a chemical dissolution process when groundwater circulates through the limestone as illustrated in Fig. 5. Carbon dioxide from the atmosphere is fixed or converted in the soil in an aqueous state and combined with rain-

water to form carbonic acid, which readily dissolves carbonate rocks. Karstic features develop from a self-accelerating process of water flow along well-defined pathways such as bedding planes, joints and faults. As the water percolates downward under the force of gravity, it dissolves and enlarges the pathways. Enlargement of a pathway allows more water flow which increases the dissolution rate. As the enlarged pathway transmits more water, it pirates drainage from the surrounding rock mass. Over time, this process results in very jagged appearance, sometimes dissect vertically and deeply into the rock terrain as seen in Fig. 6.

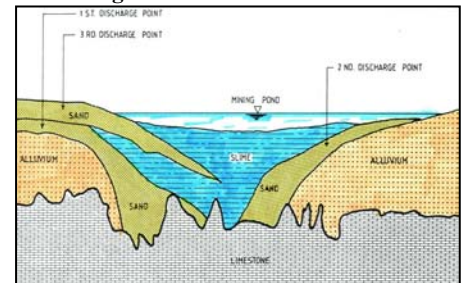


Fig. 4 Tin mining remnant of heterogeneous nature (Chan & Hong 1986)

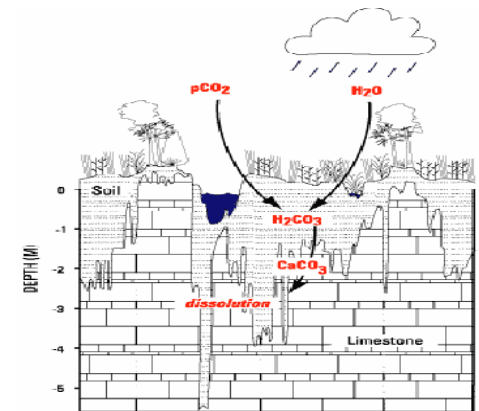


Fig. 5 Process of limestone dissolution (UCGS 2000)

Water will continue to percolate downward until it reaches the water table, below which all pore space is occupied by water. Since the rock is saturated with water, water flow slows down and so does the dissolution rate. The water table fluctuates up and down as a result of seasonal change and creates a zone of preferential dissolution along the zone of fluctuation. Over time, this process creates solution channels.

The development of subsurface karstic topography over limestone terrain is classified in five types as illustrated in Fig. 7 by Yin (1986).



Fig. 6 Originally flat limestone plateau dissected deeply by dissolution (Photo fr. Ch'ng 1984)

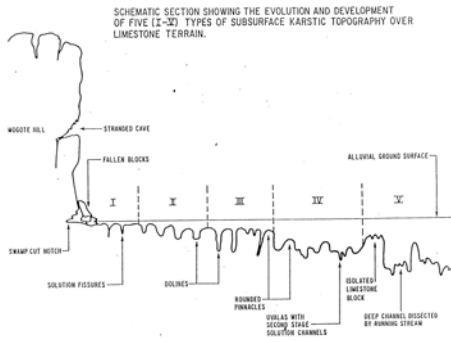


Fig. 7 Evolution and development of limestone karst (Yin 1986)

4.2 Rate of Limestone Dissolution

The dissolution of limestone is a very slow process compared to the human life span. The dissolution rate is expressed in ka (one thousand year).

Tens of thousands of years is considered a reasonable time in Kaufmann's (2004) dissolution kinetics model for limestone conduit development. Sowers (1996) quotes the rock surface denudation rates compiled by Jennings (1983) and White (1988) vary from 5mm to 200mm per ka. The maximum rate of 200mm per ka is expected for tropic climate with an annual rainfall of 3000mm.

The literature review by Fatihah & Yeap (2002) shows limestone denudation rates of 15 to 100 mm/ka in different parts of the world except Williams (1966) obtained values range from 3-6300mm/ka in Ireland.

Local research on the topic is limited. Fatihah & Yeap (2002) conducted a research on the limestone dissolution rates in the Kinta and Lenggong valleys. They left limestone samples in running streams, stagnant pond water and subaerial condition. The estimated limestone denudation rates for the three cases were 369mm/ka, 224mm/ka and 134mm/ka respectively. Exposing the limestone samples in running streams, stagnant pond water and subaerial condition is analogous of various conditions that may be experienced by limestone.

According to Sowers (1996), the collapses of limestone cavern roofs should be very rare

although many limestone caverns have experienced some roof collapse in the geological past. This is due to the very slow rate of dissolution in limestone. Moreover, the roof of a cave is not dissolved aggressively unless the groundwater flow is full.

4.3 Limestone Bedrock Profile

As shown in Fig. 1, limestone usually occurs at shallow depths of a few metres to less than 25m except in areas covered by the thick Kenny Hill formation where the limestone is encountered as deep as 200m such as at the Petronas Twin Towers (Azam et. al. 1996).

Note that cliff-like drops in limestone profile were encountered at the sites of Petronas Twin Towers (Azam et. al. 1996), Pan Pacific Hotel (Mitchell, 1986) and Bistari Condominium (Hewitt & Gue 1996). The difference in bedrock levels varies from 70m to more than 100m within the sites. Yeap (1986) attributes such abrupt rock profile to fault zone and contact zone between limestone and other formations.

4.4 Steep depressions, potholes and deep cut solution features

On a flat limestone terrain, steep depressions can occur. Such a feature was encountered in a deep excavation at a site near the junction of Jalan Cheras/Jalan Chan Sow Lin. The depression was about 27m deep.

Potholes as shown in Fig. 8 were exposed at an excavation site near Kg. Pandan Roundabout. The biggest pothole measured 11m in diameter and 8m deep. Another pothole was suspected 150m away as detected by boreholes supplemented by Mackintosh probing tests. The potholes at Sg. Besi Tin Mines observed by Ayob (1965) were 10m in diameter and 25m deep. Similar features are described as 'well like holes' by Yeap (1986). Their sizes vary from 30m to 200m in diameter!



Fig. 8 A pothole

Deep dissections as shown in Fig. 6 are common features.

It is not surprising that pile lengths vary significantly in limestone area.

4.5 Solution Channels and Cavities

It is unlikely that cavities exist in isolation in limestone. They are part of the solution channel system. Their encounters by soil investigation boreholes are commonly reported as 'cavities' locally.

Based on the author's experience, the vertical dimension of cavities encountered by boreholes is seldom greater than 3m, similar to observations by Ting (1986). Cavities are

usually partially filled or without in-fill. The in-fills are usually slimy, having low N values when Standard Penetration Tests (SPT) are conducted on them.

Large forms of solution channels are found typically in dense non-porous limestone which is thick-bedded and well-jointed (Gobbett 1965). Soft porous and poorly jointed limestone does not provide a favourable environment because groundwater flow is not concentrated into particular channels. The cross-sections of small limestone solution channels are more of arch as in Fig. 9 (b) to (f) rather than flat roof which is less stable as in Fig. 9 (a) based on observation of Wilford (1964) for small cave passages in Peninsular and East Malaysia.

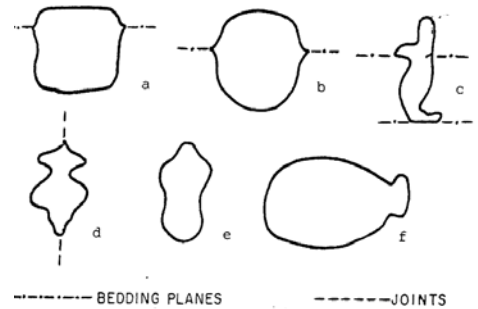


Fig.9 Typical cross sections of small cave passages (Wilford 1964)

Due to vertically developed karsts as described earlier, it is possible that a borehole drills through a limestone overhang before it re-enters the rock below. This rock free section can be misinterpreted as a cavity and a fairly big one! The materials from the rock free section usually show properties similar to materials of the overburden soils above the limestone bedrock.

The largest cavity encountered by the author was 13m (refers to vertical dimension hereafter) as revealed by a borehole. The site is located on the western side of Jalan Sentul/Lebuhraya Karak junction. The site occupies an area of 7.6 ha where a total of 38 boreholes were carried out. Another 5.2m cavity was encountered in another borehole 40m away from the aforementioned one.

4.6 Sinkholes

Sinkhole refers to a depression on the ground surface caused by dissolution of the limestone near the surface or the collapse of an underground cave.

There were a number of sinkhole incidents in Kuala Lumpur and the surrounding areas. The most recent ones occurred near Jalan Cheras (Sin Chew Daily 2004) and at Jalan Tun Razak (China Press 2004), suspected linked to an on going tunnel excavation. In 1995, a sinkhole measuring 3m diameter and 1.5m deep occurred at Jalan Lidcole (Fig. 10). The associated ground depression was 20m by 25m in size (GESB 1995). The inci-

dent coincided with borehole drilling in the vicinity and there were construction activities involving piling and excavation more than 150m away. GESB 1995 also quotes a ground depression at Jalan P. Ramlee in 1993 which was 10 times the size of that at Jalan Lidcole. It coincided with bored piling activities in the locality. A sinkhole at Datuk Keramat was recorded in the geological map by GSM (1995).

Ch'ng (1984) lists a few sinkhole incidents as reported in the newspapers: In 1968, 9 people were killed due to the collapse of a block of low-cost flat at Jalan Raja Laut believed to be due to failure of foundation on weak limestone bedrock; In 1981, 24 houses on an ex-mining land were demolished due to sinking and cracks at Taman Seri Serdang; In 1983, a sinkhole at KL-Seremban Highway near UPM caused a partial closure of the highway; In 1983, 16 units of PKNS houses on ex-mining land were demolished due to significant foundation settlement; In 1984, 10 units of double-storey houses in Taman Cheras Indah were seriously damaged due to sinkholes.



Fig. 10 A sinkhole at Jalan Lidcole (GESB 1995)

Sinkholes have also occurred in Jinjang and Kepong. In Kuala Lumpur, a 10m diameter sinkhole developed suddenly at the building site during pile driving for the Campbell Shopping Centre in 1972 (Chan & Hong 1986). Sinkhole risks associated with bored piling work are highlighted in Bauer (2004).

Almost all sinkholes are triggered by construction activities. The main triggering factors are lowering of groundwater table, loss of fines through groundwater seepage, imposing of additional loads and vibrations. In some occasions, it is due to direct punching of cavity cover by borehole or piling activities.

Locations where overburdens are thin are more susceptible to occurrences of sinkholes due to lack of 'buffer' and 'bridging effect'. For the recent sinkholes occurred near Jalan Tun Razak and Jalan Cheras, the overburden was around 3.5m thick and holes were created. Where overburden thickness increased to about 10m, there were ground depressions but no hole was formed. The incident occurred after frequent rainfalls over a short period of time. There was lack of direct evidence of groundwater table lowering. The

nearest excavation was some 175m away. Rainwater was suspected to cause extra groundwater flow that encouraged migration of fines in the soil into solution channels.

An obvious case of ground subsidence related to groundwater extraction was reported at Subang Hi-tech Park in 1998 (SSPG 1998). Some 20 units of 1-1/2 storey linked shop factories were affected. Ground subsided significantly within a period of two months during the illegal pumping of groundwater at an adjacent vacant land. When the pumping was stopped, the rate of building settlement reduced significantly. A borehole sunk during the investigation of the incident developed into a small sinkhole.

Sinkholes occasionally triggered by soil investigation boreholes in ex-mining lands where the soil covers over limestone are thin.

5. Conclusion

Like limestone in other parts of the world, erratic karst topography commonly found in Kuala Lumpur Limestone is formed by a chemical dissolution process. The dissolution of limestone is a very slow process compared to human life span.

The karsts consist of deep dissections, pot-holes, steep depressions and solution channels, resulting in erratic limestone rock bedrock profile that posts great uncertainties and challenges in foundation construction.

Sinkholes are usually triggered by construction activities due to: loss of fines through groundwater seepage, lowering of groundwater table, imposing of additional loads, vibrations, direct punching of cavity cover by boreholes or piling. Limestone covered by thin soils is more susceptible to occurrences of sinkholes.

Abrupt drop in limestone profile of 60m to more than 100m have been observed within some building sites located near contact zones or fault zones.

Acknowledgement

The author wishes to thank his colleagues and Assoc. Prof. B. K. Tan for their kind assistance.

References

- Azam T., Hashim H., & Ibrahim, R., 1996, Foundation design for Petronas Twin Towers at Kuala Lumpur City Centre, 12th SEAGC, 6-19 May, 1996, Kuala Lumpur, p485-492
- Ayob, M., 1965, Study in bedrock geology and sedimentology of Quaternary sediments at sungai besi tin mines, Selangor, BSc.(Hons.) Thesis, Geology Department, Univ. Malaya
- Bauer 2004, Malaysia - Kuala Lumpur, infrastructure blues, http://www.bauer.de/dt/spezialtiefbau/rojekte/ausland/proj_malaysia02.htm, accessed on 17-04-04
- Chan S. F. & Hong, L. E., 1986, Pile foundation in limestone areas of Malaysia, Foundation Problems in Limestone Areas of Peninsular Malaysia, Geot. Tech. Div., IEM

China Press, 29-04-2004

Ch'ng S. C., 1984, Geologi Kejuruteraan Batu-kapur Kuala Lumpur, Malaysia, BSc.(Hons) Thesis, Geology Department, UKM, Bangi, Selangor, Year 1983/84

Fatihah, R & Yeap E. B. 2002, Estimating limestone dissolution rates in the Kinta and Lengong valleys using micro erosion meter: a preliminary study, GSM Annual Geological Conference 2002

Geo-Environment Sdn Bhd (GESB), 1995, Report On Investigation On Ground Subsidence At Persiaran Lidcol, Nov., 1995, Job 31121

Geological Survey Malaysia, 1995, Geological map of Kuala Lumpur and surrounding areas, Wilayah Persekutuan Series L8010, Part of Sheet 94a, 94b, 94d, 94e & 94f, Digital process 1995

Gobbett, D.J., 1965, The formation of limestone caves in Malaya, *Malaya Nature Journal*, 19(1): pp. 4 – 12.

Gobbett, D.J. & Hutchison, C.S. 1973, *Geology of the Malay Peninsula*, New York: Wiley-Interscience.

Hewitt, P. & Gue, S. S., Piled raft foundation in a weathered sedimentary formation, Kuala Lumpur, Malaysia, 12th SEAGC, 6-19 May, 1996, Kuala Lumpur, p367-372.

Kaderabek, T. J., Reynolds, R. T., 1981, Miami limestone foundation design and construction, *J. Geot. Tech. Engr. Div. GT7*, Jul. 1981, pp. 859 -

Kaufmann G., 2004, Karst system modelling, Course lecture, Inst. of Geophysics, Univ. of Goettingen, Gemany, <http://www.uni-geophys.gwdg.de/~gkaufman/work/karst/index.html>, 16-09-2004

Mining Department, 1980-1982, Ex-mining Land Map in Kuala Lumpur and Adjacent Area, unpublished.

Mitchell, J. M., 1986 Foundation for the Pan Pacific Hotel on pinnacled and cavernous limestone, *Foundation Problems in Limestone Areas of Peninsular Malaysia*, Geot. Tech. Div. IEM.

Sin Chew Daily 3-04-2004

Sowers, G. F. 1996, Buildings on sinkholes, design and construction of foundations in Karst terrain, ASCE, New York p26

SSP Geotechnics Sdn Bhd (SSPG), 1998, Geotechnical Investigation Report on Cracks and Settlement of Factory Lots at Subang Hi-tech Park (Subang Square), Selangor, Nov. 1998, Job 31259.

Ting, W. H., 1986, Foundation problems in limestone areas, *Foundation Problems in Limestone Areas of Peninsular Malaysia*, Geot. Tech. Div., IEM.

U.S.Geological Survey (USGS), 2002, Coastal and Marine Geology Program web site, Jan 18 2002, <http://coastal.er.usgs.gov/publications/ofr/00180/intro/karst.html>

Wilford, G.E. 1964, The geology of Sarawak and Sabah Caves: 12 – 16, *Bull. 6, Geol. Survey Dept. Borneo Region, Malaysia.*

Willbourn E.S., 1921, *An Account of The Geology and Mining Industries of South Selangor and Negri Sembilan*, Geological Department, Federated Malay States.

Yeap E.B., 1986, Irregular Topography of The Subsurface Carbonate Bedrock in The Kuala Lumpur Area, *Foundation Problems in Limestone Areas of Peninsular Malaysia*, Geot. Tech. Div., IEM.

Yin E.H., 1986, *Geology and Mineral Resources of Kuala Lumpur-Klang Valley (Draft)*, Geological Survey Malaysia District Memoir.