REVIEW PAPER

STATIC AND DYNAMIC BEHAVIOUR OF KUALA LUMPUR LIMESTONE

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Abstract: It is a well known fact that the local bedrock which acts as the foundation for many surficial structures plays a major role in establishing the damage potential of incoming seismic waves due to earthquakes. Seismic activities are definitely a geologic hazard for those living in regarded prone areas, but the seismic waves are invaluable for studying the interior of the Earth. To understand the influence of seismicity to rock behaviour we must first explore stress and strain of the subject rock. Malaysia is experiencing small-scale tremors due the local and neighboring seismic activities. Limestone, being the major portion of the underlying bedrock in Kuala Lumpur, will experience dynamic behaviour due to these activities. To foresee the dynamic behaviour, the static behaviour of rocks is being considered. However, the static and dynamic behaviour of rock corresponds to the rock lithology, physical and mechanical properties of the rock. This paper reviews the properties of Kuala Lumpur limestone and foresees the probable dynamic behaviour of the rock.

Keywords: *Dynamic, earthquake, limestone, seismic, surficial structures*

1.0 Introduction

The recent engineering advancements in Kuala Lumpur metropolis and relative tectonic activities in surrounding regions has urged the engineers and scientists to take into account the ground properties forming the foundation for engineering structures. Seismic activities naturally induce the dynamic behaviour of the bedrock. Kuala Lumpur is underlain by three main rock types: limestone (better known as Kuala Lumpur Limestone), granite and Kenny Hill formation, as depicted in Figure 1.

In a nutshell, Kuala Lumpur Limestone is the sedimentary rock that was being intruded by the igneous rock (granite), as such, Kuala Lumpur Limestone comprises of sedimentary rock (limestone) and low-grade metamorphic rock (dolomite). Kenny Hill formation is a metamorphic rock formation comprising of schists, phyllites and others that were formed from the metamorphism of shale, sandstones and other similar sedimentary rocks. Kuala Lumpur Limestone underlay most part of the Kuala Lumpur area.

Several researchers have analysed different limestone formations from different parts of the world to obtain their mineralogical and chemical compositions for various reasons, from the workability of cements to the additives in improving the soil properties, either for engineering purposes or for agricultural purposes for example, (Tsivilis *et al*. 1999), (Voglis *et al*. 2005), (Smirnov *et al*. 2014), (Oliveira *et al*. 2014), (Hashemi Azizi *et al*. 2014).These mineralogical and chemical compositions will be discussed in the results and discussions section in relation to the dynamic properties of limestone.

The dynamic compression and splitting of dry and water-saturated limestone are sensitive to the strain rate (Smirnov *et al*. 2014). It is well known that one of the main problems in modeling the dynamic strength properties of materials is related to the dependence of the conventional ultimate material characteristics on the loading history and type/method of loading. The dependence on the method of force application manifests itself as a large variation in the limit variables caused by variations in the impact duration, amplitude, increase of the rate of the external force, and several other factors. Mining activities, which created the ground movements and reduction of rock mass, are capable of creating irregularities in the rock behavior (Yin *et al*. 2011).

The relation between stress-strain, rock destruction and rock strength characteristics under static and dynamic combination load showed that the rock under static and dynamic combination load is easier to break. Rocks having voids or cracks increase the elastic modulus. In addition, several conditions of the rock which properties to be studied is hard to find during the field test (e.g. confined & squeezed).

The rock dynamic behavior is a case subjected to stress and strain level in dynamic conditions. The moduli are computed as relative values to the dynamic setting. When three-dimensional load pressure exceeds certain range, the elastic modulus changes. As rock pressure increases, the rock cracks closed , and its density increased, the maximum strain rate decreases (Zhang *et al*. 2011). The greater the dynamic load factor is, the more elastic energy is. The size of the dynamic load factor relates to the aspect ratio of key rock masses, the thickness of the overburden, the mining height, the height of the fragmentized rock at the bottom of key stratum and the compaction coefficient of the fragmentized rock under the static during loading conditions (Xiaojun *et al*. 2011).

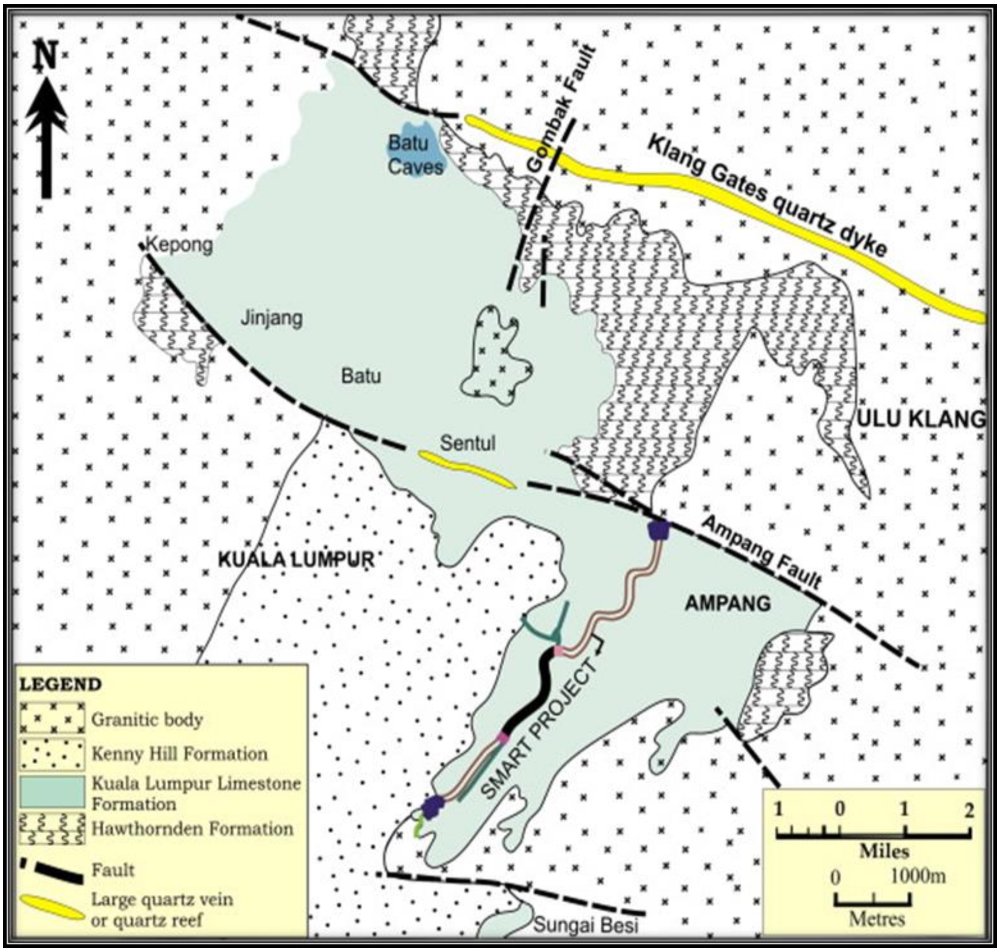

Figure 1: Geological map of Kuala Lumpur. (the Kuala Lumpur Limestone underlain most part of Kuala Lumpur area) (Zabidi & De Freitas 2011).

2.0 Materials and Methods

This paper reviews previous literatures on the properties of Kuala Lumpur Limestone and limestone from other parts of the world having similar index properties as Kuala Lumpur Limestone. The result will provide a forecast on Kuala Lumpur Limestone deformation corrosion and strain (ε) and stress (σ) amplification of wet and dry limestone. This will be followed by a discussion on the static and dynamic behavior to be forecasted on the Kuala Lumpur Limestone.

3.0 Results and Discussion

From various literatures, the basic composition of limestone is calcite existing in the form of CaCO3, CaO or similar. The presence of Mg denotes that the rock is more dolomitic in nature which is also exhibited in Table 1.

Limestone are made up of calcareous materials such as sea shells accumulated on the sea floor and lithified into a calcareous rock, namely limestone. On lithification, the calcareous materials re-crystallized into calcite minerals. When there are magnesium impurities present in the composition, dolomite is formed. In some situations, low-grade metamorphic rocks are formed due to the some igneous intrusion occurring at a distant to the limestone body.

The presented values with 10% and higher content of MgO represents dolomitic limestone which is Kuala Lumpur Limestone. Kuala Lumpur Limestone Formation is mainly dolomitic limestone while some part of the formation is actually low-grade marble, formed from the low-grade metamorphism of the limestone due to the intrusion of Kuala Lumpur granite body.

The calcareous content of the limestone causes the rock to be porous. Dry limestone maintains its integrity. However, when it is soaked, water in the pores will act as lubricant and causes the static compressive and tensile strength to reduce drastically as in Table 2 and it is also attested in Figure 2 for dynamic stress and critical stress applications.

The measurable strength of a rock sample utterly relies on the constituent properties that make up the rock mass and as well its micro structures. The strength of limestone is understood by measuring the investigating the stress (σ) and strain (ε) connection. Principally, strain (ε) analyzed against stress (σ) to form a relationship which best forecasts the behavior of the rock.

In Figure 3, highly non-linear deformation pattern of Kuala Lumpur Limestone is evidently demonstrated. Besides, the deformation mechanism of the rock can be very different under static and dynamic testing.

Moreover, rock deformation under static and dynamic loading is relative to its modulus which dependent on dynamic stress or strain level. Rock modules such as Young's Modulus (E) and Shear Modulus (G) decrease as the level of stress or strain increases. The crack corrosion features of rock are highly nonlinear and this is manifested in Figure 3.

Table 1: Chemical composition (% by weight, using X-ray Refraction Analyses, XRF) of limestone from various literatures.

Chemical Composition (%)	(Tsivilis, Chaniotakisb, Badogiannis, Pahoulasa, & Ilias, 1999)	(Voglis, Kakali, Chaniotakis, & Tsivilis, 2005)	(Abd Rashid *et al.*, 2014)	(Yusoff *et al.*, 2008)	(Azizi Hashemi, Mirab Shabestari, & Khazaei, 2014)
SiO_2	0.10-8.25	0.54	-	0.13-3.21	-
Al_2O_3	0.15-1.52	0.35	-	0.01-0.59	-
Fe_2O_3	0.02-0.62	0.12	-	-	-
CaO	47.09-53.36	51.95	55.1	20.20-22.20	44.6-55.6
MgO	0.45-4.99	1.16	-	10.00-12.00	0.53-3.30
K_2O	0.01-0.30	-	-	0.03-0.17	-
Na_2O	0.00-0.06	0.02	-	-	-
LOI	37.50-44.35	42.10	43.3	-	-

Table 2: Static strength of limestone (Smirnov *et al.* 2014).

Type of static strength	Dry Limestone (MPa)	saturated limestone (MPa)
$\sigma_c^{compressive}$	11.3	7.7
$\sigma_t^{tensile}$	3.6	1.7

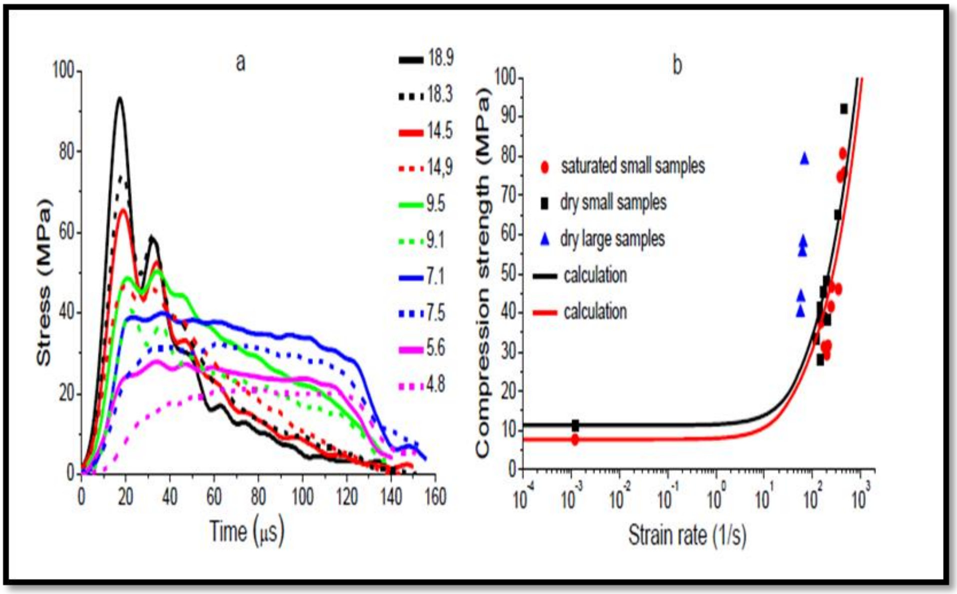

Figure 2: Dynamic stress diagram for different projectile speeds. (dry: bold lines and saturated: dotted lines (a) Classical Kolsky method) and (b) Critical stress in uniaxial compression tests, Dots: experimental data; bold lines: calculated values) (Smirnov *et al*. 2014).

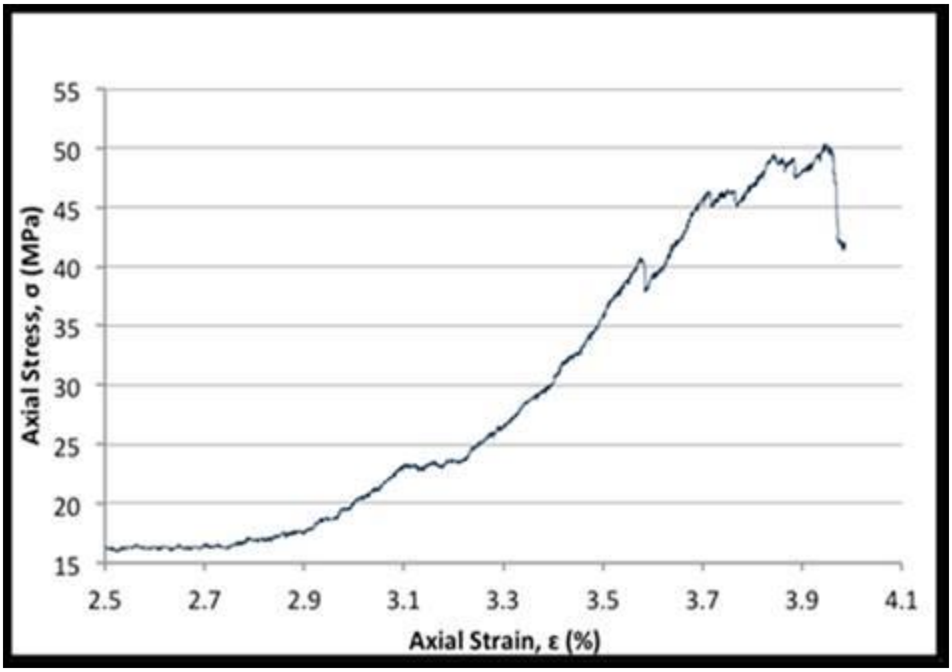

Figure 3: Non-linear Deformation of Kuala Lumpur Limestone

4.0 Conclusions

Generally, the studied data exhibits wider range of chemical composition to the percentage (%) of weight. The reduction of compressive and tensile strength of wet samples also identified. Stress (σ) and strain (ε) plot falls on non-linear pattern. These finding shows static and dynamic behaviour which regards to stress (σ) and strain (ε) is greatly in line with the chemical composition of the rock. In addition, it is highly significant to emphasize the developed model for further applicability under minute level. Therefore, alternating dynamic moduli with regard to stress-strain variables for statistically selected samples is recommended.

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