Relevance of Geoscience in Quarrying

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Abstract

The relevance of geoscience in quarrying seems pretty obvious as quarrying is the extraction of rock resource from the ground. What is less obvious is that geoscience knowledge can assist in improving productivity, health, safety, environmental and value creation in quarrying. Good drilling and blasting is the frontline of productivity in quarrying operations and geoscience assists in evaluation of drillability, blastibility and crushibility of rocks. The structure and nature of rock being quarried affect face stability and types of dust produced. Good geoscience knowledge of the quarry grounds enables better control of environmental impacts of quarrying operations and reduces potential anomalous environmental impacts. Detail geological evaluation of rock deposits assist in selective quarrying, producing higher valued industrial products rather than cheap rock materials. Quarry management should realise the importance of geoscience knowledge of their site and use it to improve their quarrying operations and profitability.

Kepentingan Geosains Dalam Pengkuarian

Abstrak

Geosains adalah penting dalam pengkuarian kerana ia melibatkan pengekstrakan batuan dari bumi. Apa yang masih kurang jelas ialah pengetahuan geosains boleh digunakan dalam meningkatkan produktiviti, kesihatan, keselamatan, alam sekitar dan nilai pembinaan dalam pengkuarian. Pengerudian dan peletupan yang baik merupakan asas produktiviti dalam pengkuarian di mana geosains berfungsi dalam penilaian kebolehgerudian, kebolehletupan dan kebolehpecahan batuan. Struktur dan tabii batuan yang dikuari memberi kesan terhadap kestabilan permukaan kuari dan jenis debu yang terhasil. Pengetahuan geosains yang baik tentang kuari membolehkan kawalan terhadap sekitaran semasa operasi dan mengurangkan kesan potensi anomali sekitaran. Evaluasi geologi terperinci tentang longgokan batuan membantu dalam pemilihan kuari dan penghasilan bahan industri yang bermutu. Pengurusan kuari seharusnya menyedari kepentingan pengetahuan geosains untuk lapangan mereka dan mengunakanya untuk mempertingkatkan operasi pengkuarian dan keuntungan.

INTRODUCTION

Quarrying is a necessity for national and industrial development. It is a huge industry. In 1996, quarries produced more than ninety five million tonnes of rock material (excluding cement quarries) with an estimated value of RM 1.6 billion ringgit. It seems amazing that such a huge industry, extracting a natural non-renewable mineral resource (geomaterial) gives minimal considerations to geological and geoscience inputs. An investor is willing to put ten million ringgit to acquire land and start up a quarry but is usually reluctant to spend a couple of thousand ringgit to do geological studies on the rock resource itself, which is the core of his investment. This maybe a case of sen wise but ringgit foolish. Geoscience information can reduce the risk of investment and improve quarrying operations and profitability.

RESOURCE EVALUATION

Many quarry operators think it is not necessary to do detailed resource evaluation. They feel the main hurdle is getting the land and once they get it they are sure to make money. Although some are fortunate to make money, others learn the expensive way that the apparently simple rock resource can hold many surprises, which they do not fully anticipate.

The overburden maybe thicker than expected, so much money has to be spent in removing the overburden before the quarry can start rock production. This has caused financial difficulties to many quarry operators and contractors. Much space is also needed to dispose this overburden in an environmentally acceptable way and space is usually a major constraint in quarries. The extent of weathering is also important as weathered rocks are weaker and may not be saleable. It is advisable to do geological investigations to estimate the thickness of the overburden before planning and starting the quarry. The overburden can be estimated by seismic refraction survey, augering, drilling or other sounding methods. Knowledge of overburden enables proper quarry evaluation, costing, planning and location of facilities. Knowledge of the overburden material may also show that it has some uses; for example to be utilised for products like bricks.

Limestone rock resources can have cavities and holes (wangs) of large sizes, causing reduction of expected reserves (Khor, 1996a). Very often this is simply accounted for by subtracting a percentage off the volume of rock observable. Detailed geological investigation can give a better estimate of reserves and rock quality. The chemical and physical quality of the rock is important if the quarry wants to produce rocks for industrial applications.

The rock to be quarried must fulfil certain specifications for it to be used for the purpose it is intended for. If used in construction, it must be strong, durable and chemically inert. Among the tests carried out are aggregate crushing value, impact value, specific gravity, ten percent fines value, flakiness index, soundness value, abrasion value, alkali silica reaction, alkali carbonate reaction and oxidation of pyrites. The laboratories in the Minerals and Geoscience Department are presently providing this service to the quarrying industry. If the rock is to be used as a raw material for industries, its purity and consistency is important.

Quarrying for dimension stone requires even more thorough geological studies like bed thickness, joint spacing, tectonic history, textural variations, mineralogical and inclusions studies and ability of the rock to withstand cutting and polishing (Khor, 1996b). Laboratory tests for dimension stone specifications include specific gravity, compressive strength, water absorption, modulus of rupture, flexural strength, coefficient of thermal expansion, impact test, hardness test and abrasion resistance. The rock resource should also be big enough and consistent to enable it to create a niche into the very discerning dimension stone market.

PRODUCTIVITY

Good drilling and blasting is the starting point of improving productivity in quarrying operations. Well blasted rocks reduce digging, loading and haulage time, eliminate the need of secondary breakage, provide better working benches thus reducing tyre wear among trucks and improve crushing operations.

The drillability of a rock is dependent among other things, on the hardness of the constituent minerals, grain size, compressive strength and rockmass structure. High quartz content rock like granite is harder to drill compared to softer rocks like limestone. Coarse-grained rocks are generally easier to drill than fine-grained rocks. The drillability of a rock is inversely proportional to its compressive strength, that is the higher the compressive strength, the lower the penetration rate. The amount of joints and cracks in the rock affects drilling progress and quality. Broken rocks cause the drilling bit to jam and discontinuities can cause drill holes to deviate. The abrasiveness of the minerals in the rock also affects the wear rate of drilling tools and therefore drilling costs. Good knowledge of the nature of the rock in a quarry assists in the selection of suitable drilling tools and also improves drill hole quality.

The geological structure and rockmass conditions of the quarry face affect the efficiency of blasting. Certain orientations of the face with respect to existing bedding and joint planes give better rock fragmentation and less toe (large unfragmented blocks at the toe of the quarry face) problems. Where possible, quarry faces should be orientated for optimal blasting. Water flowing into the blasting area through underground cracks affects the proper functioning of explosives. Better understanding of rockmass conditions at quarry faces together with better drilling, improves rock fragmentation and productivity in quarries (Khor, 1994; Khor and Samsul Kamal, 1998).

In dimension stone quarrying by the use of diamond wire sawing, the cutting speed and yield depend on the characteristic and nature of the rock to be cut. For softer rocks like travertines, the cutting speed is faster at 11 – 18 m^2/hr and for harder rocks like granite, the cutting speed is lower at 0.8 – 1.3 m^2/hr. For crystalline marble the cutting speed is about 10 – 16 m^2/hr. The yield (square metres cut for linear metre wire) for softer travertines is 80-90 m^2/m and for the more abrasive granite is only 6-9 m^2/m. For crystalline marble the yield is about 55-65 m^2 /m. The productivity of diamond wire sawing depends not only on the rock type but also on the micro and macro geological structures in the rock deposit. Cracked zones can cause diamond wire to be stuck and local areas of more resistant rocks like cherts can cause wavy cuts and other problems. Considering that the cost of diamond wires is about few hundred ringgit per metre, good geological knowledge and planning is necessary for its optimal use.

Rock crushing is an essential part of quarrying operations to produce aggregates of saleable sizes. Crushing uses a lot of energy, so the machinery and operations should be correctly matched with the rock characteristics to enable optimal operation. The Bond work index can be one parameter used to evaluate the crushibility and grindability of a rock. The work index expresses the resistance of the rock to crushing and grinding and numerically is the kilowatt-hours per short ton required to reduce the rock from infinite feed size to 80% passing 100 mm. The work index varies for different rock types.

SAFETY AND HEALTH

The structural geology of the rock plays an important role in rock stability and safety in quarries. This is specially so in quarries doing undercut blasting and with high quarry faces. Joints, bedding, solution channels and cavities at unfavourable settings can cause unexpected rock falls.

The first stage of quarry planning and development is usually to create a road up the hill after which the production benches are created. The road should be located on stable ground and orientated favourable with regards to rock structures, so that the rock faces at the sides of the road are stable and remain stable. Roads should preferably be cut across direction of dips of bedding or discontinuity planes. Areas that have potential for planar, wedge, toppling failures and loose rocks should be avoided.

During blasting, consideration must be given to the rock structures to avoid unexpected breaking out of the rock face or rockfalls. Due to the presence of solution channels, discontinuities and joints, rocks may not just break along the line of blast but also irregularly around the surrounding areas depending on the orientations of and cohesion at these lines and planes. Overhanging rocks can be left behind posing potential dangers of rockfall at unpredictable moments. Highly irregular faces also increase difficulties in carrying out future blasting. Care should also be taken of loose rocks which can be induced to fall due to vibrations from blasting. Undetected voids or cracks in the rock may cause flyrocks from blasting. Flyrock is the unusual projection of rocks during blasting to greater than expected distances and can cause injuries to people, machinery and surrounding property. Geological studies at macro and micro level, can assist to reduce the risks of potential rock falls and flyrocks, hence increasing safety in quarries (Khor, 1992).

Workers in quarries, especially rock drillers are exposed to dust in quarries. Although all dust is undesirable, some are more harmful to health than others, depending among other things on their mineralogical content. Respirable crystalline silica is more harmful than inert limestone and may cause silicosis. Deeper understanding of the mineral assemblage of the rock being quarried helps to identify severity of dust health hazards (NIOSH, 1992).

ENVIRONMENTAL IMPACTS

Among the environmental impacts of quarrying are vibration, noise, flyrocks from blasting, dust and water pollution.

Vibration from blasting depends on the blast design, maximum instantaneous charge and the ground conditions through which the seismic waves propagate from source to receiver. The attenuation of seismic waves depends on the types of rock, the conditions of the rock, the types of soil and conditions of the soil. Looser materials like soils, have higher attenuation factors than hard rock. The rock attenuation factor is also higher in weathered and fissured rock. The attenuation of seismic waves through soil depends on its compactness, moistness and ground water level. The vibration from blasting can be different in different directions from the blast, depending on the homogeneity or inhomogeneity of ground conditions. The frequencies of blast vibration propagation also depend on the rock/ground conditions. The probability of damage depends on both the amplitude and frequency of vibration so most vibration standards quote both these parameters. Some vibration standard even quotes the types of soil/rock in the ground. Understanding the geological conditions in a quarry site assist in controlling the environmental impacts of blasting vibration to the surrounding.

The intensity of noise from blasting can sometimes be higher than expected due to rock conditions at the quarry face. Open cracks, joints, mud seams and beddings may allow premature release of explosive energy giving rise to higher noise levels. Voids or cavities may unknowingly be overcharged causing violent rock movements. These micro geological features also contribute to flyrock. Good field observations and drillhole logging provide information for better charging of blastholes with explosives and reduce anomalous noise levels.

Dust nuisance is a common complaint by the public about quarrying activities. When there is a quarry around, any dust problem is usually blamed on the quarry, rightly or wrongly. The science of "finger-printing" air borne dust samples on the basis of mineralogy can provide information to find out whether a particular quarry operation is the source of dust problem and also its contribution compared to the ambient level and other dust sources. The mineralogical suite from a quarry is different from that of industries, agricultural activities or other development on sand or clay. By studying this in detail qualitatively and quantitatively, the dust contribution from each of the different sources maybe estimated (Merefield *et al.*, 1995).

Quarries store and use considerable amount of diesel and oil. Occasionally there maybe minor spillages or improper disposal of spent oils. If a major spillage occurs, it causes ground contamination and this oil spillage may also migrate into surface and ground water resources. Geological knowledge of ground conditions assist in modeling possible migration of pollutants, its hazards and how to control it. Resistivity tomography together with geological information is a valuable tool for plume migration modeling and pollution monitoring in the ground.

VALUE CREATION

Rock is a non-renewable resource and it should be exploited in a sustainable and optimal way. Quite often we hear people say that in Malaysia we marble our roads. This implies that we have not studied our resources properly and allowed good quality rocks to be wasted in applications which would have been sufficed with lower quality rocks. To exploit our rock resource in an optimal way, we have to study our resources well, know what is required by industries and match our resources to the correct applications so that we do not waste high quality rocks on low value applications. The value of rocks from quarries can vary from a few ringgit per tonne to a few hundred ringgit per tonne. Granites, besides being used for aggregates, can be exploited for dimension stone. Those rich in feldspar maybe exploited as silica/feldspar raw material for our tile and ceramic industries reducing our imports of feldspar. Rock with high Polished Stone Value (PSV) should be reserved for special applications that require this property. Certain types of rocks can be used for our rockwool and glass industries. Limestone/marble is a very versatile mineral, much needed by our industries. It can be exploited for lime, hydrated lime, fillers, ground calcium carbonate, precipitated calcium carbonate, coatings, dimension stone and other countless related uses. Geoscience knowledge together with processing technology can increase the value of quarry products and lead to the development of new industries producing high quality raw materials for our industries and export. However, unlike metals, which always have a ready market, industrial minerals have to look for or create its own market. Industrial mineral evaluation should start from the market requirements and work backward to find whether we have suitable rock resources to produce the required products.

Quarrying is not always the simple blast, crush and sell everything. Unsuitable rock material cannot be sold and low specifications rocks sell at low prices. If the rock material is going for industrial applications rather than construction or road making, specifications are more stringent and physical and chemical quality control may be necessary. This involves better geological knowledge of the rock deposit, selective extractions, selective crushing and better market knowledge. However, the rewards are there, in terms of higher prices for rocks, which fulfill industrial specifications. For example, if we have a quarry face where one area has high magnesium limestone, another area has high quality calcium limestone and yet another has high iron content, by mixing up all the rocks, during quarrying operations, the product obtained is unsuitable for industrial applications. The product would only sell as lower value construction aggregate. If we have prior information of the rock quality at each area, we can quarry and even crush it selectively to produce say high calcium limestone for specific industrial applications and other specific products for specific application fetching higher prices. Higher quality limestone can easily fetch twice the price of simple aggregates and can even be exported. However, demarcation of quality in inhomogeneous limestones or other rocks in a small scale may not be easy. This is a practical challenge to put geoscience into use for value creation in quarrying and maximising value from rock resources.

CONCLUSION

Geoscience is highly relevant to quarrying. Increasing geoscience knowledge can improve quarrying productivity, health, safety, environment and value. However acquiring information and knowledge cost time, effort and money. Generally, quarries will not look into minute details but only practical and easily acquired information that can bring visible improvements to their quarrying operations. The more complex studies will be left to the geoscientists at the universities and research organisations. The practical experience of quarry managers and knowledge of geoscientists should be put together for the betterment of quarrying and geoscience.

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