Environmental Effect of Blasting with Special Consideration to Ground Vibration - The Malaysian Experience

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IN Malaysia, blast monitoring is already a common feature especially for the blasters or shot firers who work at quarries located near residential areas or those working at construction sites where residents have already occupied their new homes. The latter is not just a precondition imposed by the authorities, who is well aware of the potential complains from the public, it is also a must for the blaster to ensure that his trade is protected. He must know the vibration limits that are acceptable to the authorities as well as to nearby residents. He also needs to know the limit that may cause damage to structures that need to be protected and also the psychological level that may create fear among the public, and plan his work accordingly.

While the physical safety of the blaster and his team is very important, public safety is even more important. Although an experienced blaster probably knows his job well, the public's main focus is that their houses are vibrating and the fear they have for their family and themselves. A single incident of excessive vibration is likely to cause a public outcry with the news splashed on the front pages of newspapers. The incident, when it occurs, may even force the authorities to issue a stop work order. The blasting work is then halted for weeks if not months. The monetary loss to the blasting contractors is horrendous.

The blaster, therefore, needs to be technically competent, knows not only about blasting work but also about the structure near where he is blasting , be savvy in public relations and record all his work properly. This is to ensure that if his case ever lands in court, he has all the documents ready to protect himself.

Blasters at work

Blast monitoring

BLAST MONITORING WORK

Blast monitoring is fast becoming a standard condition imposed by the authorities on blasting work in quarries and construction sites. The vibration limit may vary at quarries at different sites as well as construction sites because of the different government department's interest and perception. The authorities normally quote, for example, that the ground vibration limit (Peak Particle Velocity or PPV) should not exceed 5mm/s from the nearest house where people reside and an airblast (air vibration) limit of 120dB (L) which is far below the limit that may cause any damage. How this should be recorded is up to the blaster to decide. There is no guideline as to what is needed by the authorities or even a Malaysian standard to adhere to yet. Some refer to DIN, while others refer to the now defunct United States Bureau of Mines (USBM), the Norwegian, Swedish, Australian or even Japanese standard.

Besides checking for compliance with the requirements of the authorities, proper recording of the blasting work provides the blaster with legal protection against potential claim for liability of alleged damage caused by the blasting work. As Malaysians become more educated, they become more vocal and are more likely to complain of the inconvenience caused by the presence of a quarry near their homes, especially those who have just moved in without realising that their homes are located near a quarry.

Blast monitoring can also be used to evaluate the quality of blast performance. Blast design parameters such as the amount of explosives used, direction of blast, delay, pattern, distance of structure from the blasting monitoring site, etc, can be checked to determine the reason for non-compliance and, from the results, estimation on the suitable blast design for a particular site can then be decided.

If the blaster or his consultant is well versed with blast monitoring work, then he will enter new parameters such as the distance from the blasting site and the area of interest, blast design parameters such as weight of explosives (total and maximum instantaneous charge),

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blasting plan and many more besides the standard form provided by the seismograph provider. If he is not, he will simply put the seismograph at where he thinks is right and just take whatever information that is recorded by the equipment. Many do not even understand what they are recording and do not understand the importance of correct and proper recording work which can be used when a problem emerges. As long as the authorities are willing to accept the result as it is and it is acceptable, why bother to crack your head?

Blast monitoring equipment is expensive and proper monitoring work requires the understanding of blasting techniques that is far beyond the reach of an ordinary shot firer, and very few people are willing to specialise in it especially when the return is minimal. Most quarries will only invest in the equipment and training of people when the authorities decide to enforce the operational condition set in the Environmental Impact Assessment (EIA) or Letter of Authority to Quarry. However, a minimal standard needs to be set to enable the blasting engineer to properly record the blast monitoring work, and so that it is acceptable to the relevant authorities and can be used in court when the need arises.

DAMAGE CRITERIA

It is very difficult to determine the level of vibration where damage can start to be seen. A well built house is able to withstand a much higher level of vibration compared to a low cost house. Sensitive electronic equipment may be similarly damaged if subjected to high vibration levels, however, modern equipment tend to be robust and the effect can be reduced by introducing damping equipment with shock absorbing material.

Nowadays, damage rarely happens, if ever, after a single blast. It may take months before signs of damage can be seen. By then, the effect of other environmental concerns may have overtaken the event. Natural expansion and contraction of concrete due to drying effect, ground settlement, weathering, piling during construction, etc, may have caused walls to crack.

Many research works were carried out particularly in the 1960s to 1980s by USBM and in Sweden, and subsequently many other countries, on this vibration problem. There is no shortage of references on this subject. Theses and technical papers are available free of charge on the Internet, i.e. from the Office of Surface Mining, US, US Army Corp of Engineers and the International Society of Explosives Engineers, US. However, it must be remembered that the blasting technology then was not as advanced as today, where the introduction of unlimited delays by the use of the shock tube system and electronic initiation system has enabled many new possibilities.

Hundreds of tests were carried out at mines and quarries in the US to determine the safe limit of vibration to homes and structures, and many of the results had been published. Some of the results from those published papers are as shown:

Theoenen and Windes. Seismic Effect of Quarry Blasting, US Bureau of Mines, Bulletin 442, 1942

Acceleration Index
Safe Zone – less than 0.1g
Caution Zone – between 0.1g and 1.0g
Damage Zone – greater than 1.0g
Langefors, Westerberg and Kihlstrom. Ground Vibration in Blasting, Part 1-111 Water Power, 1958

Velocity Index
No damage – less than 2.8 in/s
Fine cracks – 4.3 in/s
Cracking – 6.3 in/s
Serious cracking – 9.1 in/s
Edwards and Northwood. Experimental Blasting Studies on Structures, National Research Council, Ottawa, Canada, 1959

Velocity Index
Safe Zone – Less than 2.0 in/s
Damage – 4.0 to 5.0 in/s

Nichols, Johnson and Duvall, Blasting Vibration and Their Effects on Structures, US Bureau of Mines, Bulletin 656, 1971

Velocity Index
Safe Zone – less than 2.0 in/s
Damage zone – greater than 2.0 in/s

From the viewpoint of many investigators, Particle Velocity is considered to be the best measure of damage potential. The BuMin 656 Safe Vibration Criterion is specified as follows:

> *The safe vibration is based on the measurement of individual components and if the Particle Velocity of any component exceeds 2.0 in/s, damage is likely to occur.*
>
> *Damage means the development of fine cracks in plaster. Very quickly the particle velocity 2 in/s became known as the safe limit and many regulations were and continue to be based on these.*

Additional levels of vibration based on the results of other investigations used in the Bulletin 656 are as follows:

Threshold damage (4 in/s)

Opening of old cracks
Formation of old cracks
Dislodging of loose objects

Minor damage (5.4 in /s)

Fallen plaster
Broken windows
Fine cracks in masonry
No weakening structure

Major damage (7.6 in/s)

Large cracks in masonry
Shifting of foundation bearing walls
Serious weakening of structure

The major damage zone correlates reasonably well with the beginning damage level for natural earthquakes.

In 1980, USBM in RI 8507 (Siskind Et.al) reported on the response of structure to low frequency ground vibration which resulted in increased displacement and strain, and came up with a new safe limit which takes the frequency into account.

This safe vibration level represents a very conservative approach to measure damage potential and had been criticised intensely by the blasting industry.

In reality, it must be noted that there is no lower limit beyond which damage will not occur. This is also dependent on the age and type of structure, method of construction, materials and also the degree of exposure to normal environmental stresses.

In Malaysia, no research on this subject has been documented and it is not known whether any research has been carried out at all. As such, the authorities tend to impose the lowest and stiffest vibration level, which was also adopted by a neighbouring country, without any technical or engineering basis while the consultant tends to go for the more conservative limit. Many will simply copy the stiffest standard available and recommend it in their report without considering whether the industry can implement it or not. Getting an approval is the applicants' priority; the conditions of approval can be discussed later. The industry will not object as long as the operational conditions are not enforced. They only realise this is a big problem when a government department representative decides to visit and check the blasting operation for compliance.

General Outline of Damage Criteria to Residential Structures with respect to Ground Vibration (PPV). (Oriard, 2002) is as shown:

Safe Peak Particle Velocity for Residential Structures (RI 8507)

Type of Structure	F < 40 Hz	F > 40 Hz
Modern homes-drywall interior	0.75 in/s	2 in/s
Older homes-plaster on wood lath for interior walls	0.50 in/s	2 in/s

Range of Common Residential Criteria and Effects

12.7 mm/s (0.5 in/s)	Bureau of Mines recommended guideline for plaster-on-lath construction near surface mines (long term, large scale, low frequency vibrations) (RI 8507)
19.1 mm/s (0.75 in/s)	Bureau of Mines recommended guidelines for sheetrock construction near surface mines (RI 8507)
25.4 mm/s (1.0 in/s)	OSM regulatory limits for residences near surface mine operations at distances 92-1524 metres (301-5000 ft)
50.8 mm/s (2.0 in/s)	Widely accepted limit for residences near construction and quarry blasting (BuMin 656, RI 8507)
137 mm/s (5.4 in/s)	Minor damage to the average house subjected to quarry blasting (BuMin 656)
229 mm/s (9 in/s)	About 90% probability of minor damage from construction or quarry blasting. Structural damage to some houses depending on vibration source and character of the vibrations
501 mm/s (20 in/s)	For close-in construction blasting, minor damage to nearly all houses and structural damage to some. For low frequencies, major damage to most houses

PSYCHOLOGICAL EFFECT OF BLASTING WORK

Modern human beings are very sensitive to the use of explosives especially when it is being used near their homes. They worry about the possibility of their family members or themselves getting injured or even killed. Incidents of flyrock as reported in the news scare them. They worry about their homes vibrating when blasting work is being carried out even though the vibration level caused by a garbage truck passing in front of their homes is actually higher.

Daily reports by CNN, BBC, Al-Jazeera or the local prime time news of the situation in Pakistan, Afghanistan and Iraq where tens or even hundreds of people were killed from the use of explosives really scare them.

Human beings have the ability to detect very low vibration up to 0.5 mm/s. That is why there were complains of alleged damage to homes and disturbance from the public even when the vibration reading is that low. This level is actually too low to even cause any cosmetic damage to any recent structure. Quarry operators are aghast at all these seemingly unjustifiable complaints and the authorities are also fed up at these unending complaints. However, the trend is such that the authorities, not only those in Malaysia, tend to further reduce the allowable vibration limit even lower based more on complaints and less on the damage potential to a structure. The people and not the structure is the issue now.

From a technical point of view, the best blasting consultant or even professors also cannot help much. Psychology is beyond engineering. This is when public relations, information technology and assistance from experts can help besides the assistance from the authorities.

PUBLIC RELATIONS

The industry is part of the society and contributes immensely to its wellbeing by providing the materials for the development of the country. Without the industry, there will be no

development such as housing estates, industries, highways which are being enjoyed by the society including those that live around the quarries. Developers are aware of this because they buy stone from the nearest quarry. If the quarry is closed, they have to pay more for stone because of the greater distance and thus higher transport charges. The house buyers do not know this until they move into their new homes. Even if they are informed of the existence of a quarry nearby, many may not know what a quarry is.

Research has shown that the original group of people who co-exist with the quarries from the very beginning did not complain much about quarry activities because they were part of the quarry's community either as workers, stall operators or those whose business prosper in the presence of the quarry. They also have access to the quarry's management to voice their complaints if any. Sometimes, the quarry operator contributes towards the building of a mosque or temple in the area and takes part in the local activities especially during the festive seasons. This friendly atmosphere slowly disappears when a new owner takes over the quarry, or when the earlier workers had passed away, retired and moved out, and a new group of people move into the fringes of the quarry. This is when the problem arises.

Communication between the quarry operators and the neighbours must therefore be reinstated. The friendly environment during when the quarry operators and representatives from the neighbourhood can communicate with each other must be relived so that any dissatisfaction from the latter can be voiced out. The quarry's management must show that they care about the people, environment, safety and well-being of the public, besides making sure that they continue to profit from the quarry's operation. When profit can no longer be made, surely it is time to go. Quarries must quit the practice of avoiding the public and start to tackle any problems head on.

The Quarry Association must therefore take the lead as a representative of the industry. The authorities, particularly politicians, are likely to listen to their predicament if represented by an association with a big membership instead of individual quarries or a fractured Quarry Association. Committees with expertise in this discipline must be formed to deal with the authorities such as the local authorities and government departments. Sufficient funds must be provided for research work and surveys to understand the mindset of the public. Quarries need to be where the demand for aggregates is and this suggests that the industry cannot separate itself from the public and use the argument that 'we were there first and forever'.

The professionals such as engineers can assist and offer their expertise by delivering papers at seminars and courses organised by the Institution of Engineers, Malaysia or other institutions with a syllabus that is accredited by the relevant authorities. Lecturers with professional experience should be encouraged to write books or articles related to the Malaysian practice. It would be better if the industry sponsors these activities because if the lecturer or the writer himself were to write such books, the return would not be worthwhile because of the poor demand as well as the habit of copying for free which is popular in Malaysia.

INFORMATION TECHNOLOGY

There are lots of information on explosives use and the effect on ground vibration from the use of explosives in mines, quarries and construction sites that can be obtained freely from the web. The engineering solution on how to minimise vibration levels is well documented and available in books and taught at many shot firing and advanced blasting course.

Most of the research work done by USBM on this subject is available freely also from the web. Similarly, the range of vibration limit from various countries including the US, Australia and Europe can be downloaded and used as a guideline. Those who are members of the International Society of Explosives Engineers can refer to the society's website which is also linked to those who have an interest in the industry for information such as seismograph manufacturers and software developers. Books and articles on this subject can also be purchased through them. They are not cheap but they are available. They are generally not available on Malaysian bookshelves because of the limited demand.

EXPERTISE

Knowledge is power and the public will only listen to those who have the right knowledge. To deal with the public, the blaster, the engineer and the blasting consultant must therefore equip themselves with the relevant knowledge on this subject. The regulators must also have the necessary expertise so that they can make a decent decision that will benefit both the public and the industry. Those who have the knowledge and expertise must be encouraged to share it with the industry through courses, seminars and also sponsorships by the industry.

The industry cannot expect free services because, under the current condition, it is really not worthwhile for a person to go to the US, for example, to obtain expertise on the subject, spend his own money and expect him to serve the industry on a meagre income or for free. The industry must share the cost and the benefit. The industry needs to provide scholarships or sponsorships to brilliant students to study this subject locally or overseas.

Research works are continuously being carried out on this subject by postgraduate students and researchers from many universities and institutions, particularly on the psychological and nuisance or comfort effect of blasting on the public. In fact, many theses written by these people are available from the websites of universities.

While it is generally agreed that the current technology has enabled the blasters to comply with the low vibration levels imposed by the authorities, this comes at a high

price that has resulted in everybody paying in terms of costly homes and inflated cost of aggregates and other construction materials.

CONCLUSION

While the improvement in blasting technology has enabled the blasters to reduce the vibration level to a very safe limit, this will not stop the public from complaining of alleged damages caused to their homes. The blasters and managers in the industry must not shy away from engaging the public on this subject and allow the authorities to handle this problem. They need to equip themselves with the expertise on blasting effect on the environment so that they can confidently discuss the subject with the public and the authorities.

The blasters need to continuously improve their blasting expertise to a level where they can be considered as experts and share their expertise with fellow blasters by delivering papers at seminars or even through paid lectures. They need to understand the psychology of the public who have little knowledge on explosives and help reduce the concern over their safety. Quarry operators also need to open up their quarries to allow visits from fellow quarry professionals so that everyone can learn from each other as well as allow the public to visit them at appropriate times so that they can appreciate the industry's contribution to the nation. The culture of 'open house' as practiced by Malaysians during the festive seasons may be and should be extended to quarry operators.

The engineering solution alone is not sufficient to placate the public that the industry is doing the right thing, thus the psychological dimension must be added to ensure a sustainable, secure and long life of a quarry operation.

The authorities can also help by delaying as long as possible the encroachment of housing estates on a quarry until the quarry's lease is about to end or until the quarry operator has decided that he has had enough, whichever comes first. ■

Note:

1) *The author has direct experience in blasting work from 1985 to 1996 as the Inspector of Mines in Selangor and subsequently as a Consultant Engineer specialising in explosives engineering and blasting after optional retirement from 1996 until presently and can be contacted through e-mail at lkbs66@yahoo.com or through the Institute of Quarrying, Malaysia.*

2) *Most books or articles written in the US still use vibration unit in inches/sec and not the metric unit in mm/s. (1.0 in = 25.4mm)*

REFERENCES

[1] Rock Blasting and Overbreak Control-National Highway Institute, US

[2] Environmental Management-Institute of Quarrying, UK

[3] Explosive Excavation Technology-Lawrence Livermore Laboratory, California

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[5] Determination of Blast Vibrations Using Peak Particle Velocity at Bengal Quarry, in St Anne, Jamaica – Master's Thesis, Lulea University of Technology, Sweden, 2005

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Thank you for your co-operation.