

Allowable Levels of Vibration and Noise in Excavation

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Abstract

In Malta, the amount of annoyance caused by excavation works in terms of vibration or noise needs control. The construction industry is developing rapidly. Projects are now larger and more dangerous; however, legislation seems to lag behind the speed of innovation. Consequently, many suffer damage caused to their property due to lack of necessary precaution during excavation.

The purpose of this study is to examine vibration and sound levels caused by excavation works and standard levels of vibration PPV limits and sound level limits. Four sites were chosen for the empirical study. Information and PPV readings pertaining to excavation works by blasting were collected in an attempt to adapt a constant value of acceptable vibrations.

The study concludes with a comparison of values which differ according to type of machinery used, and type of rock found on each respective site.

Chapter 1

Introduction

1.1 The need for vibration and sound measurements

Studies suggest that blasting, piling, pneumatic machinery and road traffic cause a certain amount of groundborne vibration. Moreover, such noise annoyance could be a source of major concern to occupants living in nearby residence. This concern leads to a need to assess and regulate the amount of allowable vibration so as to prevent damage to nearby buildings and to avoid unnecessary disturbance to persons living in the vicinity.

1.2 General overview

As technology evolved the development of buildings changed. Such change is evident in Malta, with demolition construction development increasing at a rapid pace especially over the past three year. Many town houses were pulled down to be replaced by apartments that are six or seven storeys high with basements that are three to five storeys below ground level.

Construction development has changed over time. Advancement in technology and powerful machinery eased the toll in workmanship and adopted a more powerful approach. However, despite the change in development, Malta still abides by the 1868 law that lays down that there should be a retention of at least two and a half feet from the adjacent third party wall. Consequently, there is no control on the allowable vibration value or on allowable noise levels. The law was probably sufficient a century and a half ago, as it was primarily released to keep the stability between one neighboring well and the other. However, this law was never intended to be used for developments going underground as there were never cases of underground developments in those days.

This law was probably sufficient in those times, as this law was primarily released to keep the stability between one neighboring well and the other. This law was never intended to be used for developments going underground as there were never cases of underground developments.

Due to the lack of strict rule of how to go about the excavation process of underground construction, Malta experiences many complaints associated with structural damage to adjacent buildings caused by vibrations during excavation works. Admittedly, contractors

tend to be more careful nowadays, as they are being kept liable for damages caused to neighbouring property. Such awareness follows accidents in St Paul's Bay, around three years ago when two persons lost their lives, preceded by a similar accident in Sliema 3 years previously with one old lady losing her life, due to lack of precautionary measures and carelessness in excavation planning.

Apart from the fatal incident that helped create awareness, contractors and developers are becoming more diligent in their work also due to the fact that building construction is more dangerous, going higher and deeper due to a higher land value. As mentioned earlier, projects are going up to seven storeys high with a basement of four to five storeys deep.

The Building Industry Consultative Council (BICC) commissioned a technical committee to address the problem and to draft a document on "Excavation and Party Walls 2005". Amongst other things, it is being proposed that a method statement be drawn up by the architect in charge prior to commencement of excavation works. The Federation of Building Contractors (FOBC) also published a statement arguing against the 0.75m law, whilst the services of a geotechnical and structural engineer should be commissioned to draw up the necessary measures to ascertain the stability of the surroundings.

To what extent is the developer allowed to create inconvenience to neighbouring property and physical/mental strain to residents? For example, neighbouring occupants are sometimes asked to move to alternative residence due to dangerous movements on the party wall resulting from basement excavation works. Admittedly, a third party owner is compensated for damages caused, but can such inconvenience be justified?

1.3 Examples of cases and complaints in Malta

A letter which draws on *The Times of Malta* of 11 December 2006:

Unhealthy demolitions

Frank Muscat, Mosta.

We are presently witnessing the destruction of our country. Beautiful villas and houses are being demolished by speculators to make way for monstrous flats. Malta again resembles the state it was in after World War II.

The government is either obtuse or naïve. Residents who are having their next-door house being demolished are strongly complaining about the damage to their property, yet the government is turning a blind eye. This is also thanks to Mepa which is allowing such demolitions. In this respect, Mepa should be renamed thus: The Malta Environment and Planning Destruction Authority.

Besides the damage to next-door property we are also being subjected to continuous noise by JCBs as early as 6.30 in the morning and above all, the fine dust we are inhaling.

The government should address this problem and at least issue new directives such as not allowing the demolition of houses in urban parts of towns and villages.

Following is an example of an insurance claim regarding damage to a pool of a neighboring property in 2007:

- The development of a block of 9 flats
- Owner has been notified by the assured that the pool of the neighboring property sustained damage during excavation works caused by the vibrations causing weakening to pool.
- Pool damage noticed after 3 months when the water disappeared from the pool.
- Architect inspected pool before development and no pool damage was found i.e. damaged due to development.
- the damages done were said to be created due to the hydraulic drill used, damaging a 2 storey house of character and the pool measuring 8.5m by 5m. The total cost of damage resulted to be of Lm 1,244.
- Result of this claim was that the insurance was not liable for the damage, as the damage caused to the neighboring property could have been foretold. So the contractor of the job was kept liable for the damages as he should have utilised less powerful machinery for excavation, since it was close to a venerable site i.e. house of character and a pool.

Report drawn on *The Times of Malta* of 2 March 2007 regarding a 200-year-old chapel in Sliema that was damaged during trenching works undertaken opposite the chapel:

200-year-old chapel damaged during trenching works



Figure 1.1: Picture of Sliema church and picture of cracks in dome.

Trenching works outside the chapel of Our Lady of Divine Graces in High Street, Sliema, are thought to have caused damage to the early 19th century chapel. Wide cracks have appeared along the walls and the dome of what is thought to be the oldest chapel in Sliema over the past few days following the start of trenching works outside.

The trenching is being done by subcontractors of AX Holdings in preparation for the laying of drainage pipes to service the hotel.

A house situated adjacent to the chapel also sustained structural damage.



Figure 1.2: Cracks in the dome of Sliema Chapel



Figure 1.3: Cracks on façade of neighboring property.

Complaints do not only arise due to damage and annoyance caused by mechanical excavation, but also as a result to blasting which is used mostly in quarries. Many complaints are expressed by owners living close by such quarries.

A letter written in *The Times of Malta* on 12 February 2007 complains of vibrations caused by the blasting effect:

Man-made tremors

Joseph Grech, San Pawl tat-Targa.

It is exactly 12.27 p.m. on Tuesday, February 6 and I wish to report two huge tremors within the last minute, which have literally shaken my house from top to bottom. These are not earthquake tremors, although they feel as if they were - these are man-made and occur regularly, practically on every week day, here in San Pawl tat-Targa, Naxxar.

We are all very well aware of the existence of the quarries down the road from us (in my case, just over half a kilometre away) - they were there before most of us built our homes here - and they must, indeed, quarry their material. But, and this is a big but, are they doing it correctly, within the established legal limits and under supervision, or are they ignoring the rules and over-detonating to suit their own purposes? If what they are doing and how they are doing it is within the rules, then will somebody please consider changing these rules? Incidentally, are local quarrying regulations in accordance with European standards?



Figure 1.4: Quarry at Naxxar

These huge blasts, with their subsequent vibration, have caused and continue to cause untold damage to property in the area. The large Naxxar water reservoir, down the road from us, is that much closer to the quarries - and sometimes I wonder...!

1.4 Objective

In this study, I gathered as much information as possible about the cause of vibrations due to mechanical equipment and blasting, and gathered information about the noise levels in this type of excavation work. I also recorded vibration and noise levels at four different site locations in Malta and attempted to come up with a solution that would reduce the amount of damage caused to neighboring building. Additionally, I outlined a method of calculating the noise levels for each respective site that would cause the least inconvenience to the area in question.

For this study to be possible, I read numerous academic papers and contemporary articles so as to familiarise myself with the subject. In particular, I made reference to BS 7385 that provides guidance on the levels of vibration above which building structures could be damaged, and also to BS 6472: 1992 and BS 4142: 1997 which provide guidelines on allowable noise level. In parallel, I spoke to various persons working in this field of my study interest such as public officials, building contractors and other architects.

1.5 Chapter map

My dissertation is divided into twelve chapters. The literature review takes up chapters 2 to 9. It consists in information about the cause of vibrations due to the formation of waves passing through the ground rock (chapter 2), followed by the effect of vibrations on building structures (chapter 3).

Chapter 4 deals with the use of explosives for demolition, followed by guidelines that reduce vibration and annoyance resulting from blasting vibrations (chapter 5).

Chapter 6 provides information about noise level and air-over pressure produced during excavation, and how to reduce these levels (and nuisance) to nearby residence.

Chapter 7 discusses vibrations in excavation works and their effect on humans, followed by examples of building cracks due to excessive vibration (chapter 8). Chapter 9 deals with the type of excavation machinery found on the market in Malta and their properties.

Chapter 10 deals with the way the vibration measurement must be recorded according to the BS 7385-1 and also describes the measuring instrument used in this study.

Chapter 11 shows the results of vibration levels in mm/s, noise levels in dB (A), and blasting used for this study. Four different sites around Malta where used as case studies.

Conclusion

12.1: Conclusion

From the recorded readings of vibration and noise taken from the 4 sites used in this study, result conclusions could be established for good practice related to site excavation regarding the vibration limit, values, and also noise annoyance limit values.

12.2: Conclusion regarding vibration levels

As from the information recorded for the maximum peak particle velocity allowed in construction vibration in different countries, the vibrations levels established from the site visits was well below the (BS 7385-2:1993) value of 12.5mm/s. So why do accidents and damage still happen in surrounding buildings?

The reason for this is that the value stated to be 12.5mm/s is supposed to be adequate for sites where the surrounding buildings have good foundations on solid rock. The reason that adjacent buildings in Malta could have some damage, which in some cases may be severe, is because the building was not built well enough at the outset of construction. Alternatively, the rock that lies beneath the building might have many cracks.

An example of a building which was not built well originally would be a house constructed directly on soil, a very common occurrence in old parts of villages in Malta i.e. the ground slab is placed on the soil surface. In such instances, as soon as excavation works in the vicinity commence, the ground slab suffers movement.

More recent constructions could be even more unstable as a soft untied storey may have been introduced at the lower levels, opening up spans with rigid overlying floor plans to cater for the provision of the car-parking.

A worst case scenario would be, if the excavation work is happening adjacent to the building and excavation is downwards, the ground slab which is supporting the walls might have some slippage causing the walls to move or even buckle outwards.

The example mentioned above is a common source of damage in Malta today. The reason being that most new developments have basements that go beyond one storey added to the

project. On the other hand, the building standing exactly next door to the new development site was never meant to withstand such a drop exactly on the other side of the party wall. Thus, as the excavation works go deeper than the foundation level of the old building, movements occur and *konsenturi* start to appear.

Another reason why buildings sometimes move is again the fault of the new construction style. Most of the new developments currently built have one or two and sometimes up to 5 storey basement included in the project. The adjacent building to the excavation site might end up moving slightly due to the fact that Maltese rock consists of a lot of fissures. So when excavation goes beyond the existing foundations, and bad fissures are encountered, these fissures might end up sliding or falling off, leaving the existing building with a gap underneath. This might result in movement to the building or even worse collapse of the slab as this is not designed to take a cantilever moment. These risks due to fissures could be reduced by taking core tests on site before excavation commences, in order to get an idea of the texture of the existing rock underneath. This practice is gaining popularity with big developments in Malta, however, core tests are still considered an unnecessary expense to the owner of small developments.

The examples mentioned above suggest that the 12.5 mm/s cannot be adopted for construction works in Malta. Damage to buildings is not only caused by vibrations produced by the construction machinery but a combination of vibrations, a weak sediment rock and poor adjacent construction.

Noting the above on existing weak building constructions, should not it be considered that lower PPV values are entertained (refer to table 3.2). Over these past two to three years, contractors have become more cautious during excavation as accidents are becoming more frequent due to projects that involve deep basements.

Today, in many of the construction sites where excavation work is being done adjacent to party walls, contractors are abiding by the rule of keeping 75cm away from the party wall when it comes to using the hydraulic hammer, and the rest of the 75cm is then removed by using the hydraulic milling cutter. This reduces the amount of vibration that reacts on the wall, and under the adjacent dwelling. This system helps reduce the damage to adjacent dwellings but is only effective up to a certain depth. This system is effective when

excavating up to 2 - 2.5m for a sub-basement but does not make any difference when used in excavation works which go nearly 2 storeys down in line with an adjacent building. In such case, if the rock is weak in that area or the building was built on weak foundations, rock slippage and movement of the building are possible.

The findings in chapter 11 also suggest that the difference in vibration levels between coralline limestone “tal-qawwi” which was the rock found at ta’ Zuta quarry and globigerina limestone “tal-franka” found at Marsascala site had a difference in PPV of 2 mm/s..

12.3 Recommendations regarding vibrations

This dissertation suggests that there cannot be a specified peak particle velocity that one can adopt for Malta as the strength of the rock around the Island varies and the construction of the adjacent building could be weak in the first instance.

The approach to different projects must be different.

Case 1: Where excavation works are to be carried out in a site surrounded by an existing dwelling or dwellings around its boundary and is to be excavated up to not more than 2 to 2,5m as shown in figure 12.1 the method mentioned before where the site is excavated up to 0.75m from the party wall by using a hydraulic hammer of larger than type 3 from table 9.2 is sufficient enough not to cause any damage to the adjacent building. This is due to resonance not have a serious effect on the premises.

From Chapter 3 paragraph 3.6 a typical Maltese town house appears to have a natural period of vibration given at 4Hz. Chapter 2 paragraph 2.10 states that the forcing vibration should be kept 25% outside forcing vibration range. Thus the forcing vibration range should be less than 3Hz or more than 5Hz. The rest of the rock is then excavated by the use of a hydraulic milling cutter as shown in figure 12.2, if rock face is seen as being firm and compact. Otherwise, further strengthening measures should be adopted.



Figure 12.1: 0.75m away from party wall.



Figure 12.2: Use of hydraulic milling cutter.

Case 2: In cases where excavation works are to be carried out on a site that is surrounded by third party property along the site perimeter and the excavations are planned to go deeper than 3m from the third party foundation level as shown in figure 12.3 it is suggested that core tests are undertaken before excavation works commence. The core results that show the properties of the existing rock indicate whether to excavate to such a depth. If the core tests show that the rock is strong, excavation works can be carried out. If the rock is weak and highly damaged then it must be the responsibility of the architect-in-charge to take the necessary precautions.

For example, the type of machinery to be used must be chosen diligently. Also, if the rock is highly damaged, it might be better to use anchors in the rock, as one goes deeper. Another precaution may be to prop the site from one side to the next until the new structure is strong and stable enough to take the load itself. It is important to point out that for this to be possible, the site must not be very wide.



Figure 12.3: 3 stories below street level.



Figure 12.4: Badly fractured rock

Case 3: Where excavation works are being carried out on a site where its parameter is not touching a third party property, extreme precaution of excavation work is unnecessary. On the other hand, the types of machinery used for excavation depends on the distance of the site from the nearest third party property. If the property is very far away, there is little or no chance at all of possible damage to dwelling. However, if the third party property is, for example, two meters away, than the necessary precautions must be taken so as to reduce the risk of damage to a minimum. This is done by using less powerful hydraulic hammers rather than very powerful ones. The difference in case of hydraulic hammer type varies depending on the distance from the third party because as suggested in previous chapter, vibrations decrease with distance travelled.

For this case one can also take into consideration the 45 degrees between the depth of the excavated site and the property. If the angle between the depth of the excavation and the beginning of the property is 45 degrees than it is very unlikely that damage will be caused. For example, if the depth of the excavated site is 9m and the distance to the first property dwelling is 9m then there is very little risk of damage as shown in figure 12.5 (a) below. On the other hand, if the depth is 9m and the distance is less than 9m then caution must be taken with regards to vibration, due to movement of rock as shown in figure 12.5(b) below.

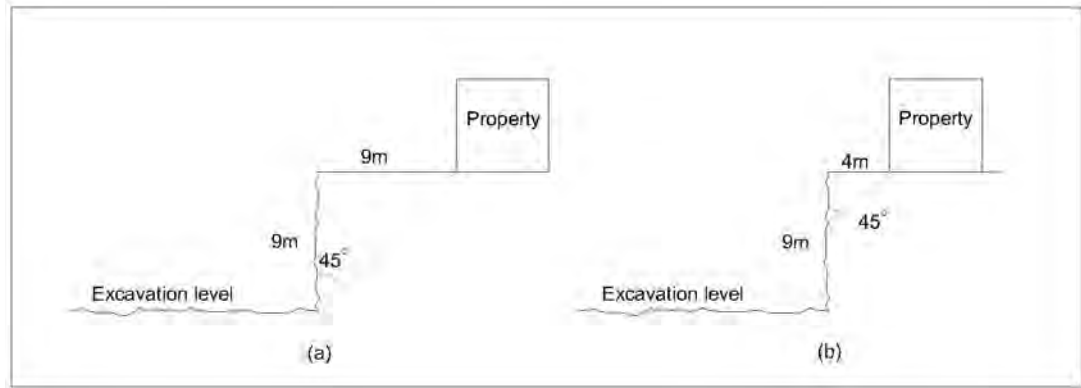


Figure 12.5(a): unlikely that damage will be caused, Figure 12.5(b): caution must be taken due to slippage of rock

12.4: Conclusion regarding Sound results

From the results gathered for this study it can be concluded that the noise nuisance level varies depending on the type and location of the site. Excavation equipment suitable for that particular site may be determined by the location type of the site.

For example in site which is usually considered as a busy and noisy area, such as the site in Ballutta, St Julian's, one may afford to use large equipment producing reasonably high levels of sound. However, in quiet areas such as the site chosen for this study in Marsascala, which is a residential area, one must be more careful on the type of equipment chosen so as to respect the surrounding community.

As stated in the BS 4142:1997 reduction in complaints and annoyance to the surrounding community is achieved if the sound level produced does not exceed 10dB above the level of the back ground noise in that particular location when construction equipment is not in use. An example of this working is shown in Chapter 10.2.8.2.

12.5: Conclusion regarding blasting results

Findings in chapter 10 suggest that blasting seems to be under control. MEPA stated a PPV limit of 8mm/s and the study results show that there never seemed to be explosions that went higher than 8mm/s. The highest reading was 6.86 mm/s.

As for the air-over pressure, the limit stated for blasting in Malta must not exceed 120 dB(A) where in some cases this limit was exceeded. Although this limit was exceeded, there seems to be no problem in Malta as this is hardly ever the case. If the same quarry continues to exceed this limit, then there are strict rules by MEPA that if the quarry owner does not reduce these levels his licence is taken away.

Although these results seem to be satisfactory, there still are many complaints reported to MEPA and on print media. These complaints are due to human reaction to sudden movement and large noise. Vibration is felt much more when inside a dwelling as a result of the air-over pressure created. That is why it is very important for contractors to inform the surrounding community about the time, date and duration of blasting as this would reduce shock to persons inside the dwelling.

12.6: Implication for future research

In terms of future research, several areas seem to be most promising. The control of noise levels caused by excavation works in different areas is an issue that can be easily controlled and can start being implemented in the construction of Malta as this is not a very complicated issue. The outstanding area appears to be insufficient legislative control locally.

As for vibration control more detail must be undertaken in the study of rock types in Malta as the problem of damage seems to occur due to the weak rock formation encountered in Malta, which is excited due to the forcing vibration of the mechanical equipment used on site for excavation works. In parallel with amendments to Maltese legislation should be undertaken.

The fundamental natural frequency vibration characteristics of typical Maltese constructions referred to casually in text requires further in-depth study, as these require consideration with the forcing vibration of the excavating equipment, for the multiplying effect of resonance to be mitigated.

Blasting measures appear to working satisfactorily with a PPV value adopted of 8mm/s. However, in the case where water retaining structures or historical sites are in the

immediate vicinity, further studies ought to be undertaken to evaluate the lower PPV value necessary for these site conditions.

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