ASSESSMENT OF VIBRATION MINIMIZATION STRATEGIES FOR CONSTRUCTION WORK IN RAILWAY PROTECTION ZONE

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ABSTRACT

Malaysia’s rapid development had pushed construction closer to existing railway system which is defined as railway protection zone and this brings concern as it might cause damage to the railway infrastructure. Five stages of information assessment and strategy development are used in this research which consists of verification for vibration limit on railway track structure, identification of limitation and strategy availability, strategies assessment and distinguish vibration related strategies, validation of the vibration related strategies and design of the vibration minimization strategies. The research was conducted in collaboration with Malaysia Land Public Transport Commission (SPAD) for the strategies assessment and strategy development. From the assessment and strategy development, the selected regulations have been assessed and selected according to type of restricted work and type of railway track structure. Based from the assessment, the selected vibration limit on railway track structure is 15mm/s ppv for both continuous and intermittent vibration while only 10mm/s is allowed on signalling and telecommunication infrastructure of the track. The result of the assessment and validation was the final strategies in five main categories based on type of restricted work. Each category shows detailed strategies according to type of structure. These strategies were compiled into a preliminary guideline of construction vibration minimization strategy in Railway Protection Zone. This is a new guideline which can be used as a future railway protection zone regulation in Malaysia.

ABSTRAK

Pembangunan pesat di Malaysia terutama dalam pengangkutan kereta api membawa banyak pembinaan terutamanya di kawasan yang sangat ketat seperti teras bandar atau kawasan berhampiran dengan penduduk yang tinggi. Pembinaan juga tertumpu ke kawasan yang berhampiran sistem kereta api sedia ada yang ditakrifkan sebagai zon perlindungan kereta api dan ini membawa kebimbangan kerana ia mungkin menyebabkan kerosakan kepada infrastruktur kereta api. Peraturan dan garis panduan yang sedia ada adalah tidak khusus pada kawalan getaran untuk pembinaan di zon perlindungan kereta api. Garis panduan Jabatan Alam Sekitar (DOE) hanya memberi tumpuan kepada had kawasan kediaman, perdagangan dan perindustrian. Peraturan Kereta Api (Perlindungan Zon Keretapi) 1998 hanya menunjukkan had getaran asas dan hanya memberi tumpuan untuk melindungi transit aliran ringan infrastruktur (LRT). Lima peringkat taksiran maklumat dan pembangunan strategi adalah digunakan dalam kajian ini iaitu pengesahan untuk had getaran pada struktur landasan kereta api, mengenal pasti had dan ketersediaan strategi, strategi penilaian dan membezakan strategi berkaitan getaran, pengesahan strategi berkaitan dengan getaran dan reka bentuk getaran strategi pengurangan. Kajian ini dijalankan dengan kerjasama Suruhanjaya Malaysia Pengangkutan Awam Darat (SPAD) untuk penilaian strategi dan pembangunan strategi. Dari pembangunan penilaian dan strategi, peraturan yang dipilih telah menilai dan pilih mengikut jenis kerja yang terhad dan jenis struktur landasan kereta api. Had getaran dipilih pada struktur landasan kereta api adalah PPV 15mm/s untuk kedua-dua getaran berterusan dan terputus-putus manakala hanya 10mm/s adalah membenarkan pada isyarat dan infrastruktur telekomunikasi trek. Maklumat berkaitan strategi juga telah disahkan dengan standard untuk digunakan dalam perancangan strategi pengurangan getaran yang boleh digunakan sebagai masa depan peraturan zon perlindungan kereta api di Malaysia.

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LIST OF SYMBOL AND ABBREVIATIONS

AG	-	At grade
CGS	-	Centre of Graduate Studies
DB	-	Dubai
DOE	-	Department of Environment
EL	-	Elevated
FKAAS	-	Faculty of Civil and Environmental Engineering
HK	-	Hong Kong
KTMB	-	Keretapi Tanah Melayu Berhad
LRT	-	Light Rail Transit
LTA	-	Singapore Land Transport Authority
MRT	-	Mass Rapid Transit
MY	-	Malaysia
RPZ	-	Railway protection zone
RTS	-	Railway track structure
SG	-	Singapore
SPAD	-	Malaysia Land Public Transport Commission
UG	-	Underground
PPV	-	Peak Particle Velocity
PVV	-	Peak Vertical Velocity

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CHAPTER 1

INTRODUCTION

1.1 Background of research

Railway transportation system in Malaysia is transforming into a higher level as the government has decided to invest RM 160 billion on railway transportation development. This includes the latest Malaysia mega project, which is the Mass Rapid Transit (MRT) Phase 1 consuming RM 50 billion investment due to the project high prospect and demand. Besides that, the future mega project that has also been announced was the Kuala Lumpur to Singapore High Speed Rail (New Straits Time Malaysia, 2013).

As the development is increasing, the construction work will also increase. There will be a lot of construction to bring the vision to reality including construction in a very tight area such as the central part of the city or near a highly populated area. This is complying with the main objective of railway transportation which is to reduce traffic problem and long commute time. This condition will lead to more limitation and strict rule during construction such as the size of the equipment and the method that is being used so that the construction suits the condition of the environment requirement especially in term of noise and vibration.

Besides new construction in a difficult urban area, construction near the existing railway system is also being a concern as it might cause damage to the existing rail track structure. This sensitive area is referred to as a Railway Protection Zone which is more than six meter from the rail track according to the area and track design and specification (Ministry of Transportation Malaysia, 1998).

1.2 Problem statement

Apart from the limitation, constructions in railway protection zone have to proceed. This leads to the main issue of determining the method or strategies in minimizing the effect of the construction to the existing infrastructure. This includes the effect of vibration which can be high enough to cause structural damage of the railway infrastructure.

Current vibration guideline seems limited for construction within railway protection zone. Department of Environment (DOE) guideline is focusing on the limitation of residential, commercial and industrial area. In term of railway infrastructure, less consideration has been taken into consideration.

In 1998, the Malaysian government has gazetted the Railway Protection Zone into the Railway Act 1991 and is being used until now. The main strength for the current regulation is more to light rail transit (LRT) infrastructure. The guideline could be improved in order to consider newer development for the railway industry in Malaysia; for example the monorail, MRT and even the new electrified double track by the Keretapi Tanah Melayu Berhad (KTMB).

1.3 Research objectives

This research is targeted to achieve these objectives:

(i) Identify the current regulation and guideline related to construction work vibration in railway protection zone for local and international authority.

(ii) To distinguish vibration related strategies from the current selected railway protection zone regulation and guideline.

(iii) To design the vibration minimization strategies for future Malaysia Railway Protection Zone development.

1.4 Research scope

Identification of the regulation especially for local regulation requires collaboration with Malaysia Land Transport Authority (SPAD). Engaging such authority is important to have strong basis for the research especially to obtain controlled document.

The assessment will be focusing on vibration related strategies which is involving construction work in a railway protection zone. There has been a full evaluation which is considering the international regulation and guideline to design the final vibration minimization strategies.

1.5 Significance of research

Development of regulation and guideline is very important to suit the industrial needs such as construction control and operations. This research will identify the insufficient detail in the existing standard for controlling vibration during construction within railway protection zone in Malaysia.

Based from the information, development of vibration control strategy could be suggested. The research can also be a part of the preliminary investigation to enhance the existing regulation.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discusses the literature review requires for the research. The literature review for this research will cover information relating to railway protection zone, guideline and regulation for railway protection zone, railway track structure, and restricted activity in railway protection zone.

Based from the objective of the research, the main idea is to have a sufficient information especially relating to railway transportation. It is important to understand why vibration is a sensitive issue which may either be affecting the environment or to the railway infrastructure itself.

Vibration knowledge is also important as to relate to the engineering aspect of the railway construction. From the findings, the best strategies to minimize the construction vibration effect can be determined.

2.2 Railway protection zone

Railway protection zone (RPZ) is defined as a designated area near railway track structure (RTS) by the authority which is protected from any development unless with permission from the authority (Ministry of Transportation Malaysia, 1998).

RPZ is a part of the authority initiative to ensure safe and reliable operation. Regulating by the law to protect the railway infrastructure is important to ensure that the safe operation in railway is maintained (Dubai Road and Transport Authority, 2012).

It is important that the restricted activity to be controlled within the RPZ. This is due to the fact that the restricted activity may cause damage to the railway. Thus, it is potentially disrupting rail service (Singapore Land Transport Authority, 2009).

2.2.1 Reserves area

There are various terminology used by the regulation and guideline to specify the critical area of the RPZ. This critical zone requires more stringent control measures than the remainder of the RPZ (Dubai Road and Transport Authority, 2012). This means that most restricted work is prohibited within critical zone.

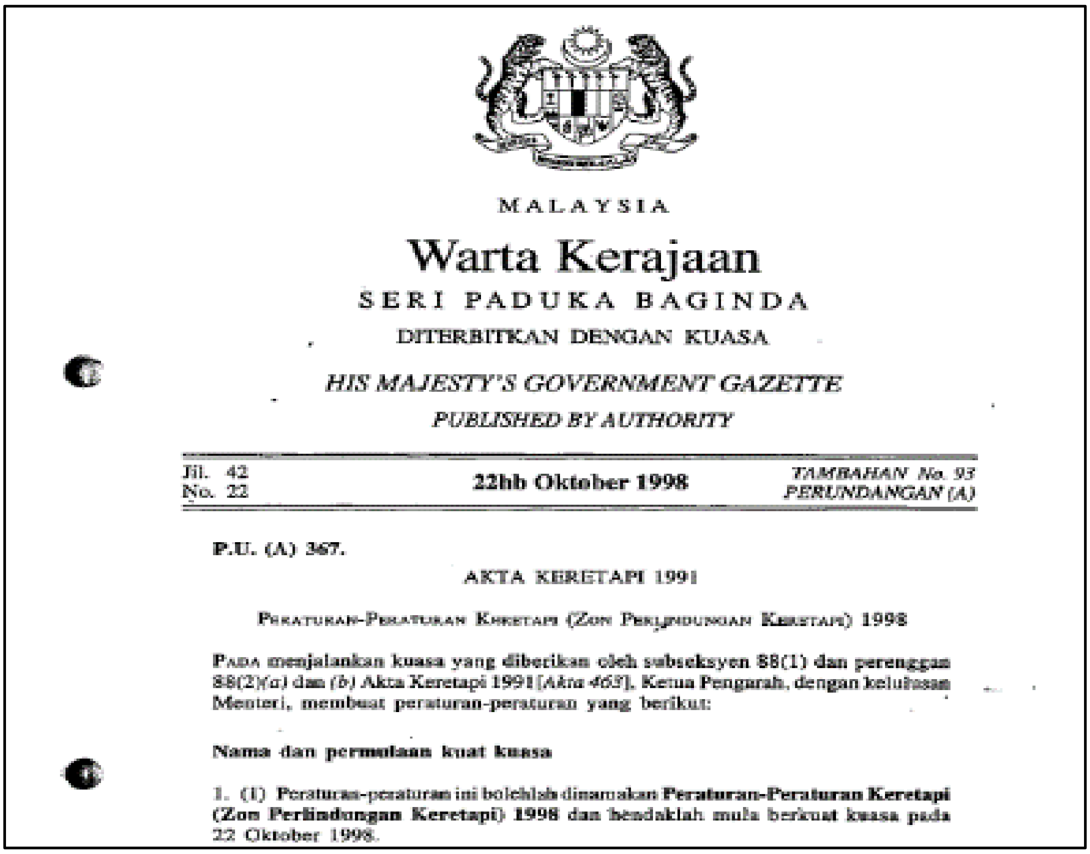
Malaysia Railway Act for RPZ uses the term first and second reserve where the first reserve is referring to the critical area of the RPZ. The first reserve is between 3m and 6m from the centreline of the RTS. While the second reserve varies according to RTS type and design (Ministry of Transportation Malaysia, 1998).

2.3 Guideline and regulation for railway protection zone

2.3.1 Malaysia

Malaysian government has announced a gazette in 1998. In the gazette, a new regulation for Railway Act 1991 was added by the Ministry Of Transportation focusing on railway protection zone. This regulation is called the Railway Regulation (Railway Protection Zone) 1998.

The regulation however only limits to the technology used in year 1998. It consists of, railway protection zone for LRT tunnel, underground station, elevated LRT track, and on ground LRT track. Thus, it does not consider other types of railway transportation especially the latest technology such as monorail and Mass Rapid Transit (MRT).



MALAYSIA

Warta Kerajaan

SERI PADUKA BAGINDA

DITERBITKAN DENGAN KUASA

HIS MAJESTY'S GOVERNMENT GAZETTE

PUBLISHED BY AUTHORITY

Jil. 42 No. 22	**22hb Oktober 1998**	*TAMBAHAN No. 93* *PERUNDANGAN (A)*

P.U. (A) 367.

AKTA KERETAPI 1991

PERATURAN-PERATURAN KERETAPI (ZON PERLINDUNGAN KERETAPI) 1998

PADA menjalankan kuasa yang diberikan oleh subseksyen 88(1) dan perenggan 88(2)*(a)* dan *(b)* Akta Keretapi 1991 [*Akta 463*], Ketua Pengarah, dengan kelulusan Menteri, membuat peraturan-peraturan yang berikut:

Nama dan permulaan kuat kuasa

1. (1) Peraturan-peraturan ini bolehlah dinamakan **Peraturan-Peraturan Keretapi (Zon Perlindungan Keretapi) 1998** dan hendaklah mula berkuat kuasa pada 22 Oktober 1998.

Figure 2.1: Front page of Malaysia 1998 gazette (Ministry of Transportation Malaysia, 1998)

The regulation is categorized according to the type of railway structure. There are underground, elevated and at grade structure with each contained either similar or different regulation to be followed by the party who wish to develop or construct within the RPZ.

2.3.2 Dubai

Dubai Road and Transport Authority (RTA) has established The Dubai Railway Protection Code of Practice. The purpose is to identify the railway protection zone and the restricted activity for all railways in the Emirate of Dubai. The code of practice is an initiative to ensure safe reliability of the operation for the railway industry. RTA believes that to ensure its safe operation, it is necessary to regulate by the law to protect the railway infrastructure, the staff, and the travelling public.

The code of practice contains detailed explanation for different type of restricted activities. From there, the guideline for controlling restricted activity is categorized according to the type of restricted activity. This is different compared to the Malaysia Railway Act 1991 that has been categorized according to the type of RTS.

In addition, the regulation also provide a guideline to design the development proposal, site inspection, monitoring requirement for the RTS and risk assessment.

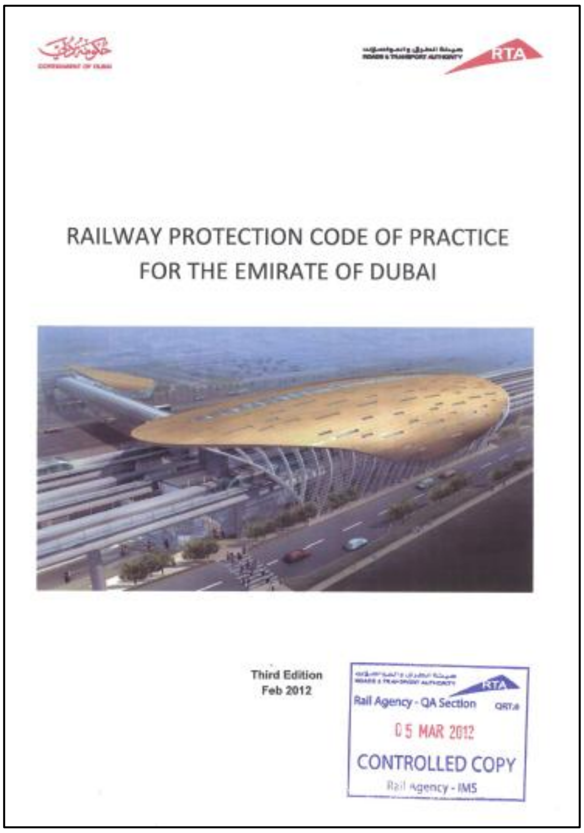
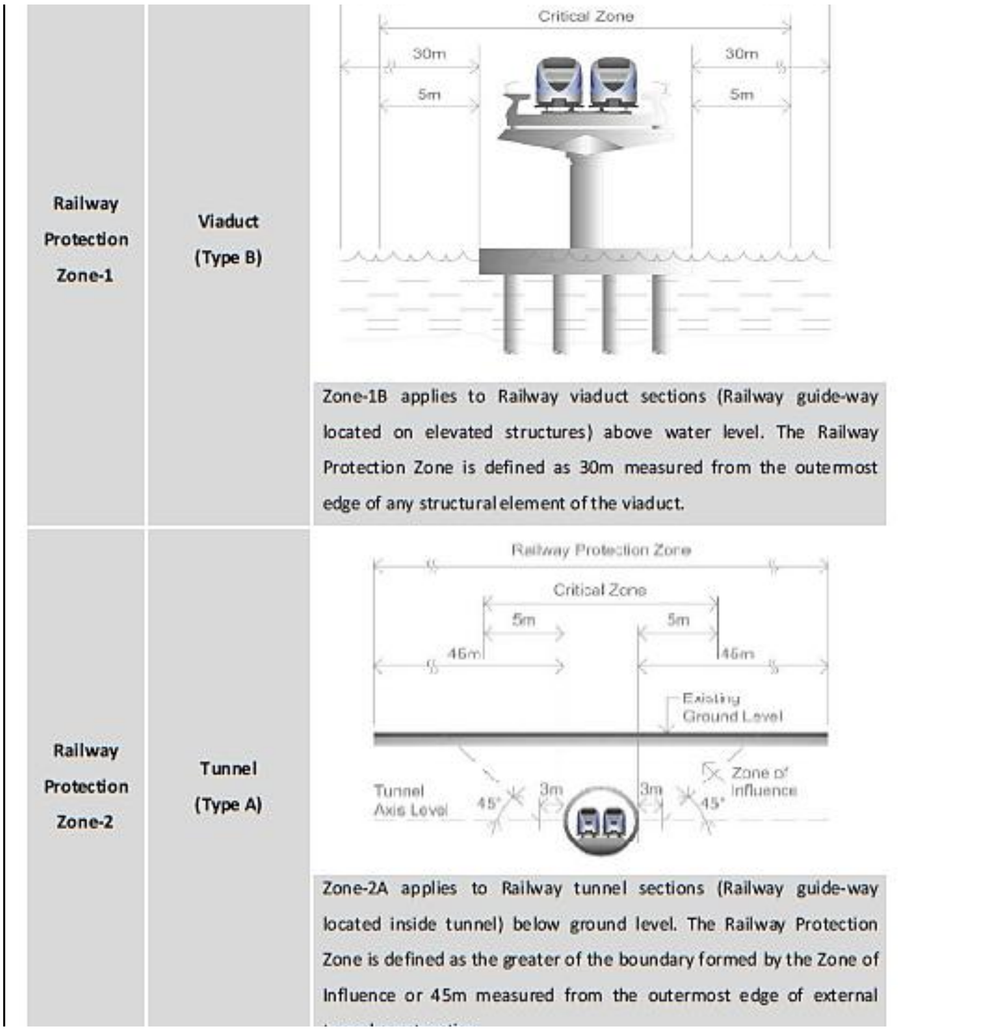


Figure 2.2: Dubai Railway Protection Code of Practice (Dubai Road and Transport Authority, 2012)

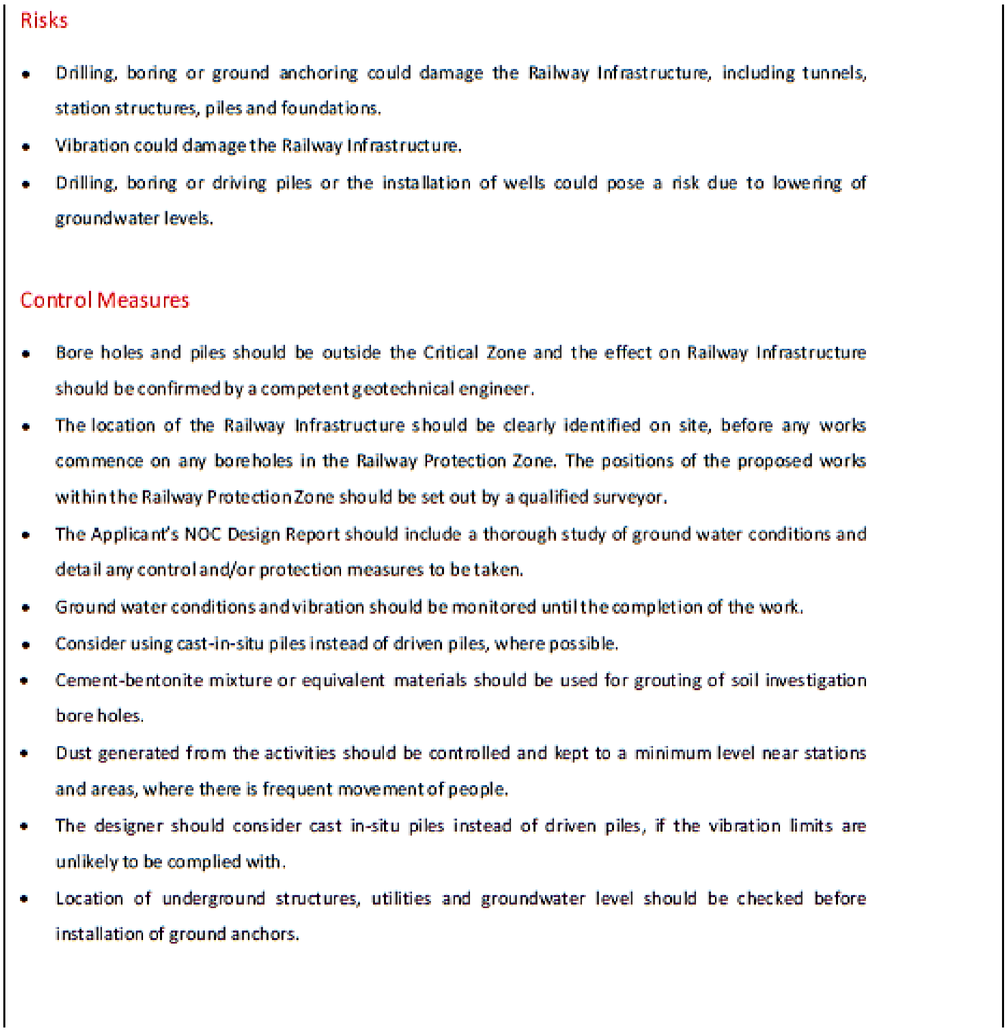
Figure 2.3 shows one of the specifications for the RPZ according to type of RTS. It is well organized and easy to understand especially in determining the zone of influence as shown in figure below.



Railway Protection Zone-1	Viaduct (Type B)	Zone-1B applies to Railway viaduct sections (Railway guide-way located on elevated structures) above water level. The Railway Protection Zone is defined as 30m measured from the outermost edge of any structural element of the viaduct.
Railway Protection Zone-2	Tunnel (Type A)	Zone-2A applies to Railway tunnel sections (Railway guide-way located inside tunnel) below ground level. The Railway Protection Zone is defined as the greater of the boundary formed by the Zone of Influence or 45m measured from the outermost edge of external

Figure 2.3: Specification for railway protection zone (Dubai Road and Transport Authority, 2012)

The guidelines highlighted the risk of each restricted activity together with the control measure. By understanding the potential risk for the risked activity, planning for the control measure will be more effective to be applied during operation. Figure 2.4 shows the display for the guideline of the restricted activity.



Risks

- Drilling, boring or ground anchoring could damage the Railway Infrastructure, including tunnels, station structures, piles and foundations.
- Vibration could damage the Railway Infrastructure.
- Drilling, boring or driving piles or the installation of wells could pose a risk due to lowering of groundwater levels.

Control Measures

- Bore holes and piles should be outside the Critical Zone and the effect on Railway Infrastructure should be confirmed by a competent geotechnical engineer.
- The location of the Railway Infrastructure should be clearly identified on site, before any works commence on any boreholes in the Railway Protection Zone. The positions of the proposed works within the Railway Protection Zone should be set out by a qualified surveyor.
- The Applicant's NOC Design Report should include a thorough study of ground water conditions and detail any control and/or protection measures to be taken.
- Ground water conditions and vibration should be monitored until the completion of the work.
- Consider using cast-in-situ piles instead of driven piles, where possible.
- Cement-bentonite mixture or equivalent materials should be used for grouting of soil investigation bore holes.
- Dust generated from the activities should be controlled and kept to a minimum level near stations and areas, where there is frequent movement of people.
- The designer should consider cast in-situ piles instead of driven piles, if the vibration limits are unlikely to be complied with.
- Location of underground structures, utilities and groundwater level should be checked before installation of ground anchors.

Figure 2.4: Risk detail and control measure to conduct a restricted activity in railway protection zone (Dubai Road and Transport Authority, 2012)

In order to facilitate the misunderstanding, it is important to have a graphical guideline to assist the planning for conducting restricted activities in the RPZ. Figure 2.5 shows one of the examples.

following:

a) approves in writing all sides of the trench as safe from collapse; and

b) states in writing how long the approval lasts if there is no stated natural occurrence that could affect adversely the stability of the trench; and

c) states in writing the natural occurrences that could affect adversely the stability of the trench.

- Stockpile, over-burden or other materials must not be placed on the edge of the excavation (this includes earth moving machinery).

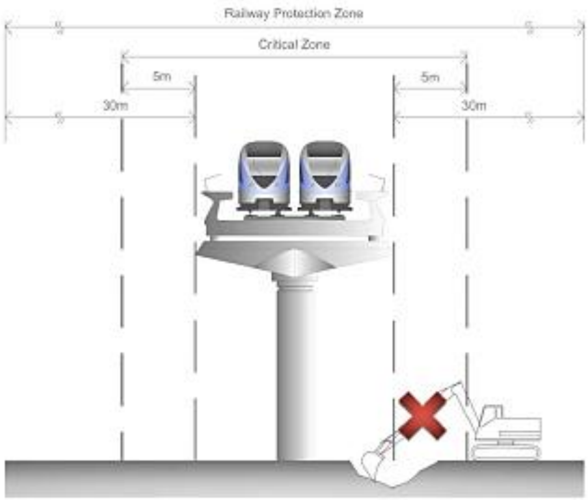


Figure 4.10: RA6 - Excavation or earthmoving activities within the Critical Zone should not be carried out before engineering analysis has been undertaken

Figure 2.5: Graphical guideline for certain restriction (Dubai Road and Transport Authority, 2012)

2.3.3 Singapore

The guideline was developed by the Land Transport Authority (LTA) of Singapore. This guideline is useful to guide any person to carry out restricted activities within the railway protection zone and the safety zones. There are also examples of some approved activities within close distance to railway infrastructure with illustration of good practice.

Singapore Railway Protection Zone Guideline is categorized based on the type of restricted activities. It is similar to Dubai code of practice. However, Singapore guideline contains more illustrations which offer better appearance and effective understanding of the user as shown in Figure 2.6 and 2.7.

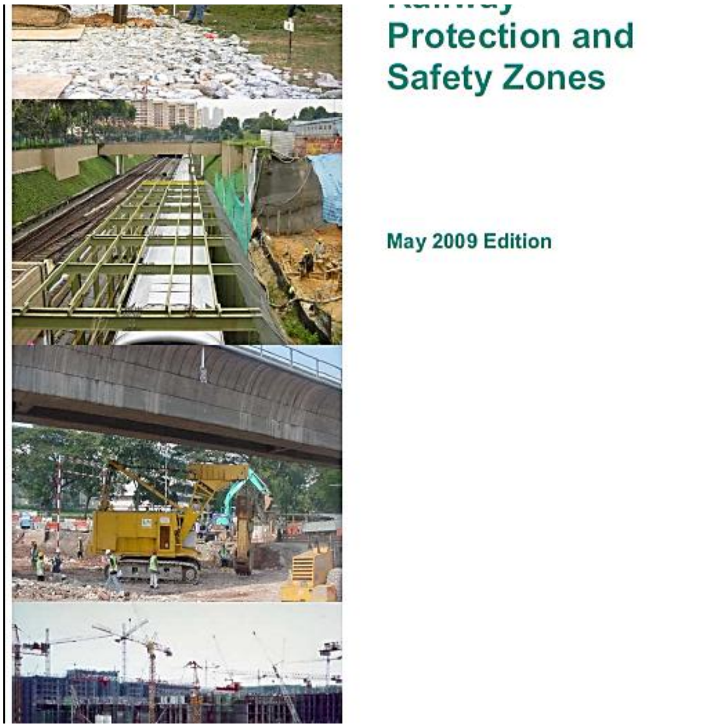


Figure 2.6: Singapore Railway Protection Zone Guideline (Singapore Land Transport Authority, 2009)

tunnels and under the viaduct.

- The use of vibratory equipment should be controlled to ensure that the vibration on the rapid transit system structure will not exceed a peak particle velocity of 15mm/s to avoid damage of RTS structures.
- The movement and operation of excavator and drilling equipment under the viaduct may damage the lightning protection system or the drainage system of the viaduct or accident knock the viaduct structure.
- Trench excavation above shallow underground RTS station roof and tunnels which are generally about 1.5m deep is not allowed to prevent damage. The shallow tunnels areas include the following:
  - Sims Ave East/Changi Road (Junction of Chai Chee/ Siglap Road)
  - Padang Jeringau
  - Henderson Road
  - Woodlands Industrial Park D Street 1
  - Sengkang East Way

Precautionary measures and safety control

Figure 2.7: Excavation guideline with illustration (Singapore Land Transport Authority, 2009)

2.3.4 Hong Kong

In Hong Kong, a set of technical notes is released by Mass Transit Railway Corporation Limited (MTRCL). The technical notes is purposely to safeguard the safety and stability of the railway structure (Mass Transit Railway Corporation Limited, 2007).

The technical notes provides regulation by categories, using both type of RTS and type of restricted work. The contents are:

(i) General information
(ii) Underground railway structure
(iii) Overhead railway structure
(iv) At grade railway structure
(v) Operation of stationary lifting appliance
(vi) Mobile lifting appliance
(vii) Maintenance of road lamp standard
(viii) Fire service department / Police force vehicle
(ix) Storage of material
(x) Demolition works

Generally, 30m is delineated from outside surface of a RTS as the RPZ if there is no fence or wall. Specific railway protection area is defined in detail drawing attached with the document. In term of construction vibration control, the guideline provides basic vibration limitation such as vibration value on RTS during construction (Mass Transit Railway Corporation Limited, 2007).

2.3.5 British standard on vibration control

The British standard for vibration control is the BS 5228-2. The research is considering the revised document in 2009. BS 5228 consists of two parts which are part 1 and part 2. Part 1 is for noise while part 2 is for vibration.

The document contains information and a guide to conduct vibration induced construction work including the effect of vibration to nearby residences. The main information is the control of vibration consisting practical measure to reduce vibration from construction and vibration mitigation strategies. Table 2.1 and Figure 2.8 shows the vibration limiting value for cosmetic damage. The vibration limiting values are different for reinforced structure and unreinforced structure.

Table 2.1: Transient vibration limiting values for cosmetic damage (British Standards Institution, 2009)

Table B.2 Transient vibration guide values for cosmetic damage

Line (see Figure B.1)	Type of building	Peak component particle velocity in frequency range of predominant pulse	
		4 Hz to 15 Hz	15 Hz and above
1	Reinforced or framed structures Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	50 mm/s at 4 Hz and above
2	Unreinforced or light framed structures Residential or light commercial buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

NOTE 1 Values referred to are at the base of the building.

NOTE 2 For line 2, at frequencies below 4 Hz, a maximum displacement of 0.6 mm (zero to peak) is not to be exceeded.

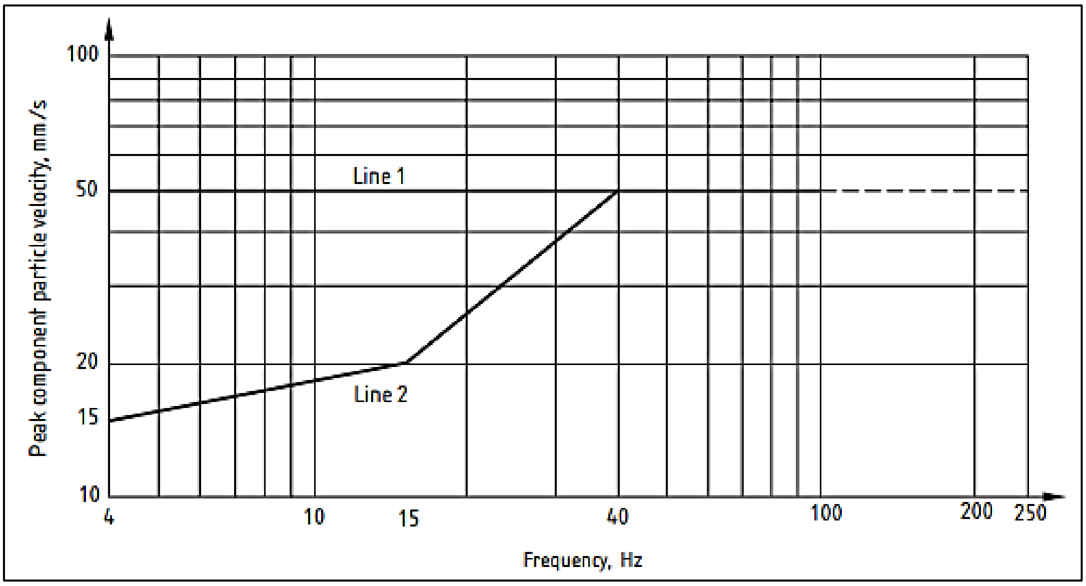


Figure 2.8: Transient vibration limiting values for cosmetic damage (British Standards Institution, 2009)

2.3.6 Department of environment vibration guideline

In Malaysia, there is a guideline published by the Department of Environment in 2004 for the first edition and 2007 for the second edition. Table 2.2 shows that the recommended vibration limitation which may effect on nearby building. The table is referring to the curve in Figure 2.9. These provide information for vibration limit on structure in Malaysia in order to prevent damage to the structure.

Table 2.2: Building short term vibration limitation (Department of Environmental Malaysia, 2007)

Type of Structure	Vibration Velocity v_i [mm/s] at foundation (as defined by the respective rating curves of Figure 1)	Vibration Velocity v_i [mm/s] at plane of floor of uppermost full storey (all frequencies)
Industrial buildings and buildings of similar design	Curve C	40
Commercial building, dwelling and buildings of similar design and/or use	Curve B	15
Structures that, because of their particular sensitivity to vibration, do not correspond to those listed above, or of great intrinsic value (e.g. residential houses, or buildings that are under preservation order)	Curve A	8

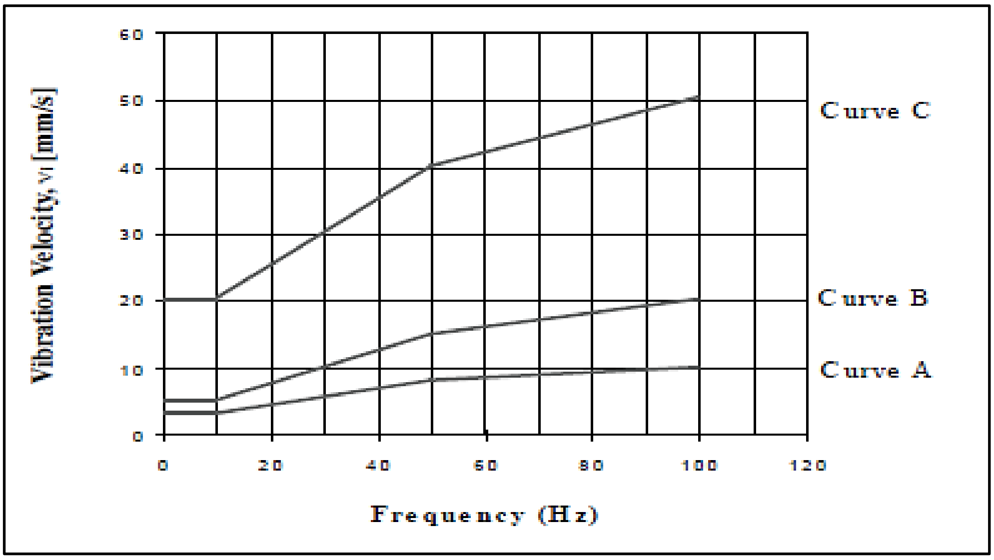


Figure 2.9: Vibration limit curve for Table 2.2 (Department of Environmental Malaysia, 2007)

2.4 Railway track structure

Malaysia Railway Protection Zone Regulation is using type of RTS to categorize the guideline. Thus, this subtopic discusses three types of RTS according to Malaysia Regulation.

2.4.1 Underground structure

Underground structure is any development works of any structure in whatever manner below the surface of the ground. This includes tunnel and portal structure that is the entrance into underground track from the surface track.

Depending on the type of tunnel, the first reserve can be around 3 to 6 meter. The second reserve of the underground railway structure can be described from the centre of the structure until 45° line drawn from the centre line of the structure as shown in Figure 2.10 and Figure 2.11 as well (Ministry of Transportation Malaysia, 1998).

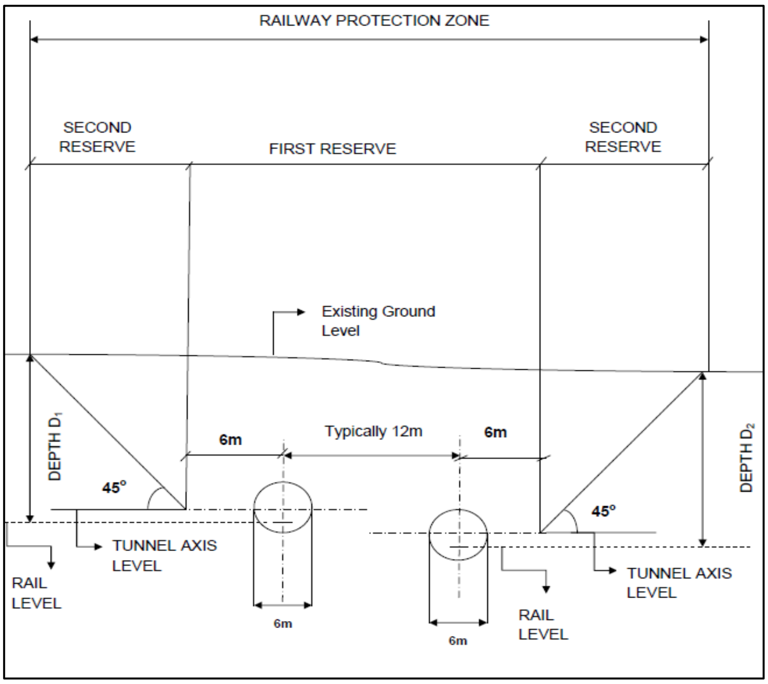


Figure 2.10: Railway protection for bored tunnel (Ministry of Transportation Malaysia, 1998).

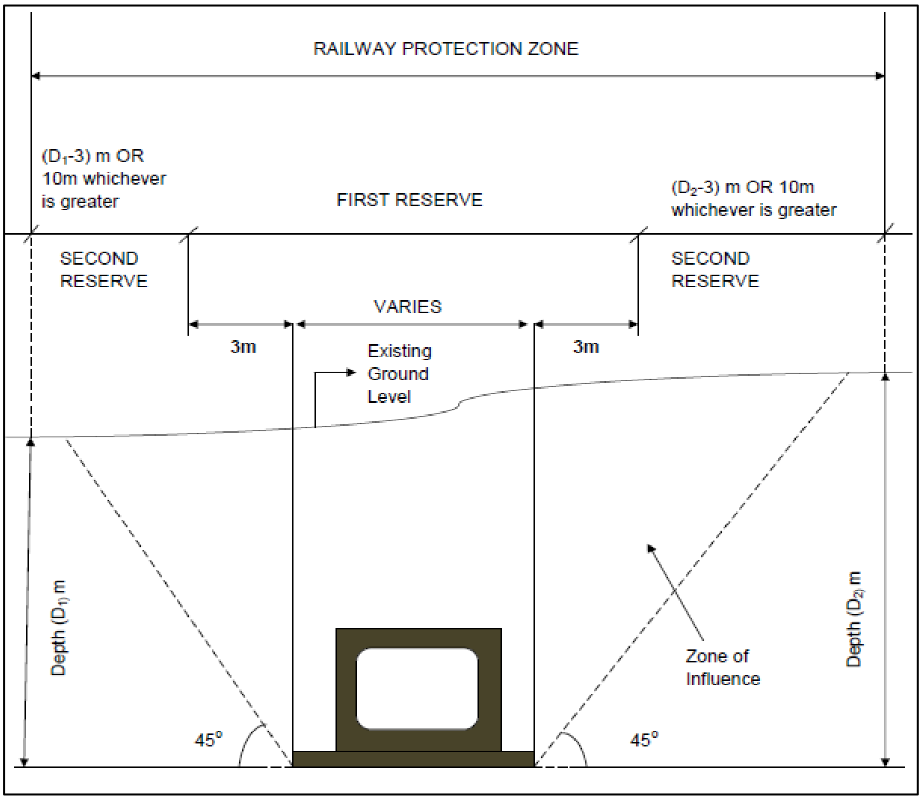


Figure 2.11: RPZ for cut and fill tunnel or underground station (Ministry of Transportation Malaysia, 1998)

2.4.2 Elevated structure

Elevated structure is any development work or of any structure in whatever manner above the surface of the ground. The main part of elevated structure is the elevated track such as elevated LRT track or monorail track. Recently, there is another type of elevated track which is the MRT elevated track.

The railway protection zone for the elevated track is shown in Figure 2.12. From the figure, it is showing that the first reserved is taken from the tip of the above structure with 6 meter distance. While the second reserve is taken from the centre line of the structure until the 45° line drawn from the maximum pile depth.

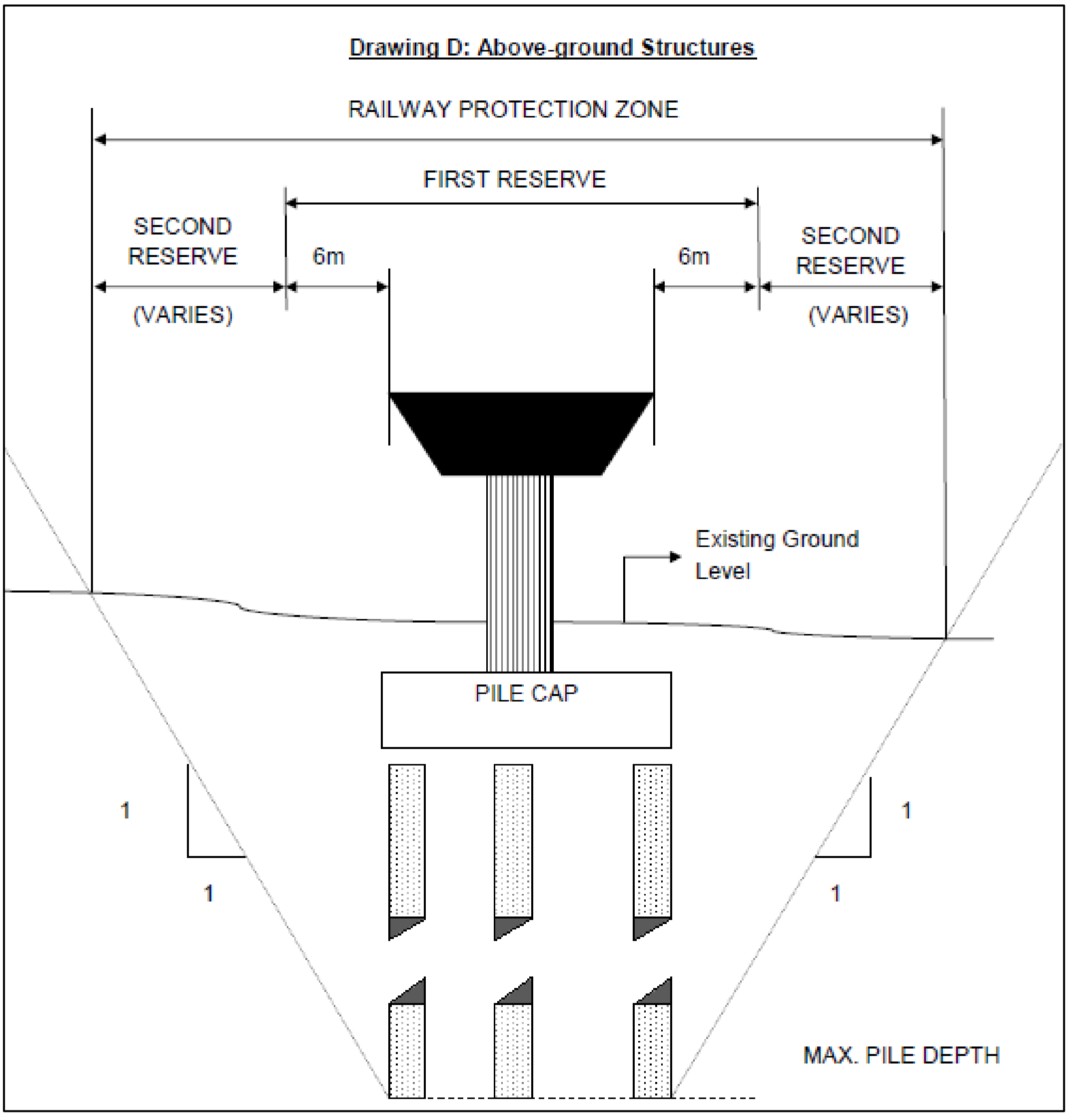


Figure 2.12: Railway protection zone for elevated structure (Ministry of Transportation Malaysia, 1998)

2.4.3 At grade structure

At grade structure means any section of the railways with tracks at ground level or on any embankment, or on an in-cutting. The railway protection zone for at grade structure is shown in Figure 2.13. The figure shows that first reserve of the RPZ covers all areas within the fences. While the second reserve is the next 6m starting from the first reserve borderline.

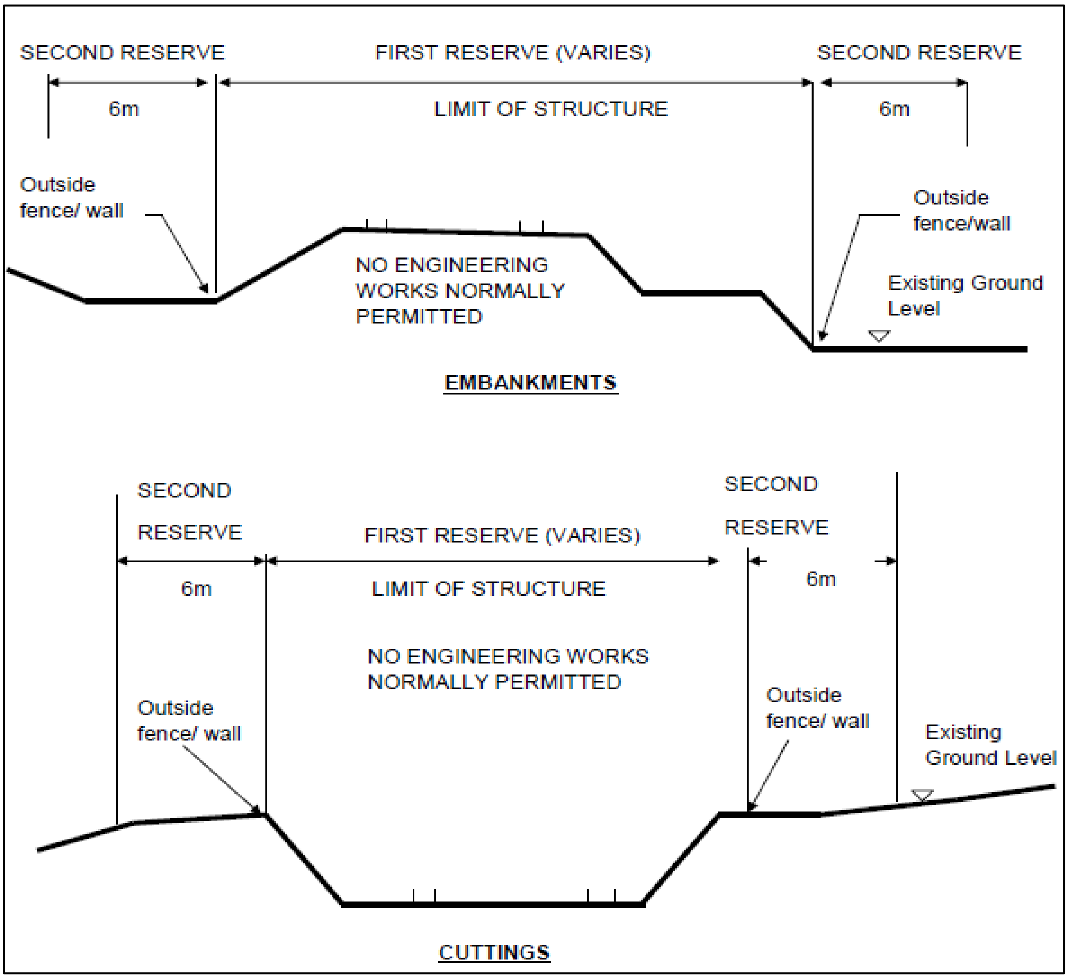


Figure 2.13: Railway protection zone specification for at grade railway structure (Ministry of Transportation Malaysia, 1998)

2.5 Restricted activity in railway protection zone

The activity that is prohibited or should be controlled within the RPZ to avoid damage to RTS. There are basically eleven types of restricted works that should be controlled within the railway protection zone (Dubai Road and Transport Authority, 2012). Table 2.3 shows the summary of the restricted work.

Table 2.3: Restricted activity in Railway Protection Zone (Dubai Road and Transport Authority, 2012)

Activity No.	Restricted Activity
RA1	Storage of goods
RA2	Movement or operation of cranes, hoists and other lifting equipment
RA3	Installation of boreholes and wells
RA4	Dredging of sea-beds and canal-beds
RA5	Construction of underground passageways
RA6	Excavation of trenches and earth movement
RA7	Demolition
RA8	Use of explosives and fireworks and the lighting of fires
RA9	Erection of scaffolding and other temporary structures
RA10	Installation or replacement of conduits for any utilities
RA11	Other activities to be controlled

Based on these, not all restricted works are vibration induced. Referring to the risk assessment provided by the regulation, there are five main restricted works in which may cause in damaging the structure. The five vibrations induced restricted works are:

(i) Bore hole, pile, well, and anchor installation
(ii) Construction of underground passageways
(iii) Excavation of trenches and earth movement
(iv) Demolition
(v) Use of explosives

2.5.1 Installation of boreholes, pile, anchor and wells

This restricted activity involved installation of boreholes, wells, piles, ground anchors and horizontal tie-backs. Piling work is the work to install the foundation into the ground to distribute loading from building to the ground. The work usually use massive piling machine in which may induce large amount of ground borne vibration (Athanasopoulos and Pelekis, 2000).

Drilling, boring or driving piles or the installation of wells could pose a risk due to lowering of groundwater levels. Besides that, vibration from drilling, boring or ground anchoring could damage the Railway Infrastructure, including tunnels, station structures, piles and foundations (Dubai Road and Transport Authority, 2012).

Commercially, there are many types of piling machine available in the market. However, piling equipment can be categorized as a conventional piling which induced high level of vibration. On the other hand, the silent piling machine which have around fifty to sixty times reduced vibration level compared with the conventional piling machine (White, 2002).

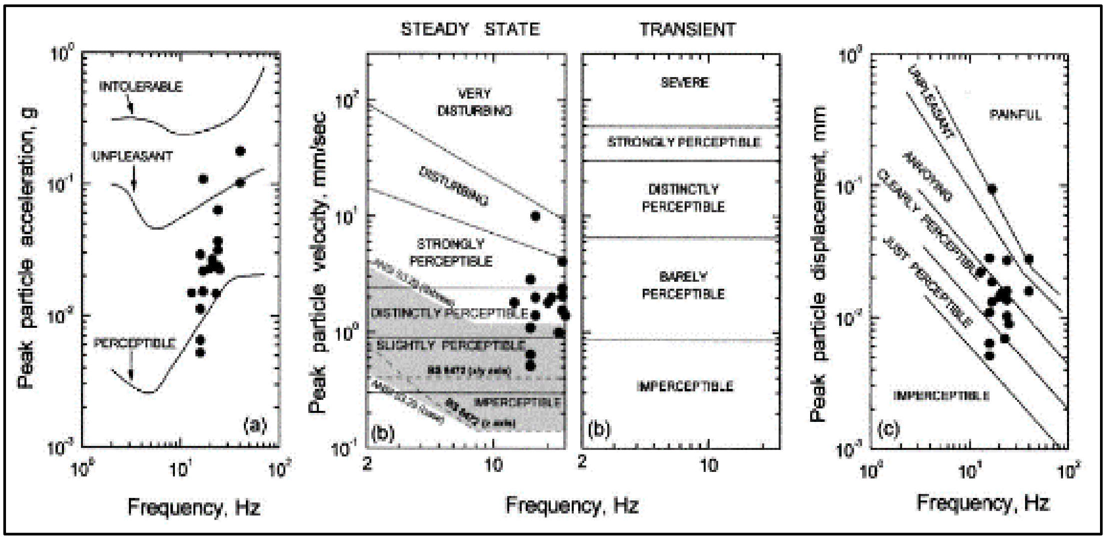


Figure 2.14: Superposition of floor vibration data on the diagram of vibration criteria for human discomfort (Athanasopoulos and Pelekis, 2000)

There was a research on measuring vibration from piling work (Athanasopoulos and Pelekis, 2000). The researcher used vertical and horizontal geophones which were installed at three points. The result was collected directly into a portable computer and with software as presented in Figure 2.15 and 2.16.

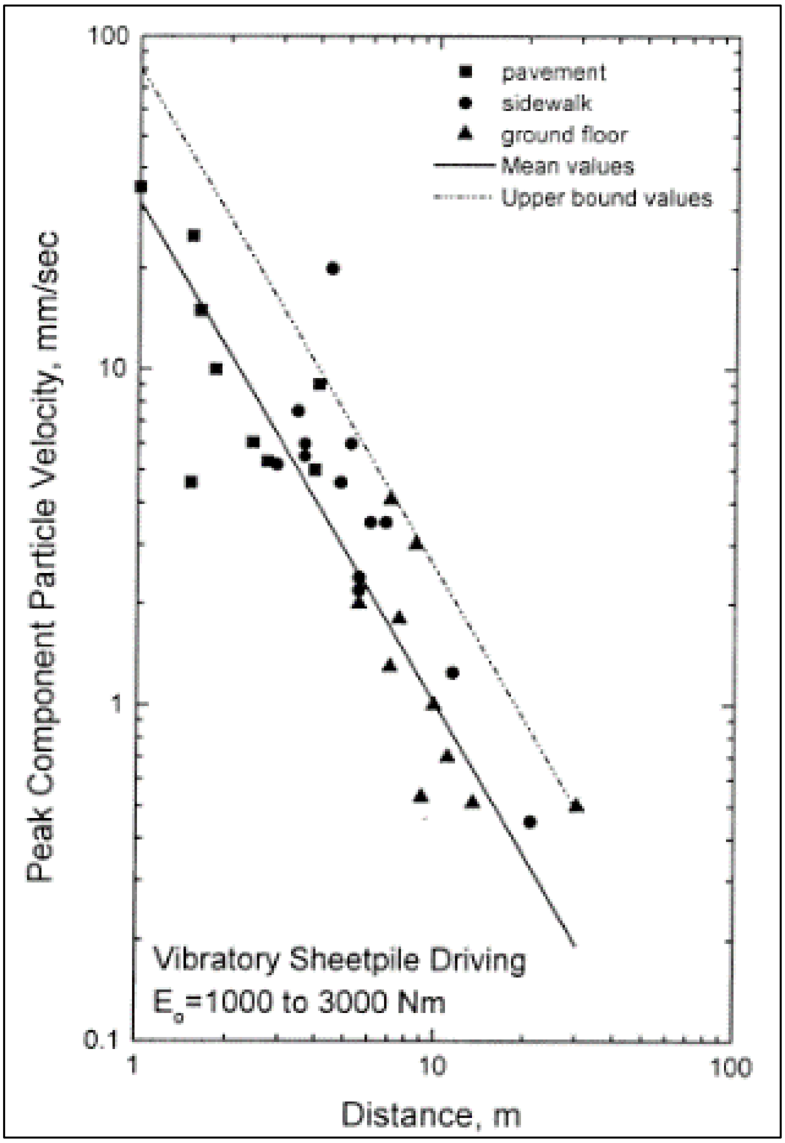


Figure 2.15: Particle velocity versus distance (Athanasopoulos and Pelekis, 2000)

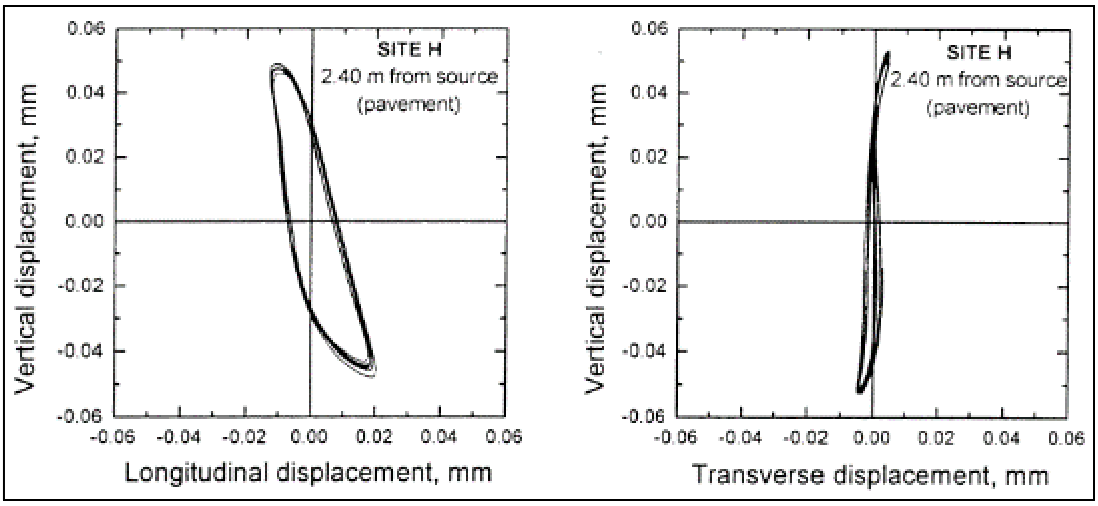


Figure 2.16: Particle displacement paths (Athanasopoulos and Pelekis, 2000)

2.5.2 Construction of underground passageways

The construction of an underground passageway can be passageway, conduit for utilities, or to provide access for people, and also vehicles path to an underground work site. Tunnelling and excavation works may cause changes to the original ground conditions, such as excessive ground loss or change in groundwater conditions; movement and vibration may affect the Railway Infrastructure (Dubai Road and Transport Authority, 2012).

2.5.3 Excavation of trenches and earth movement

The restricted activity consist excavation of trenches or pits, the carrying out of earthworks and backfilling, or the shifting or pushing of earth or soil from one area to another, whether or not such activities are carried out manually or by mechanical means. Possible risks are:

(i) The operation of excavation equipment within the Critical Zone may damage the Railway Infrastructure.
(ii) Excessive vibration generated by machinery used for excavation or earth moving within the Critical Zone may cause damage to the Railway Infrastructure.
(iii) Changing groundwater conditions.
(iv) Excavation adjacent to the Railway Infrastructure may change existing storm water conditions.
(v) Excavation collapsing causing the destabilizing plant or Railway Infrastructure.

A study has been conducted to investigate the deformed Taipei Mass Rapid Transit (TRTS) caused by adjacent excavation work (Chang and Wang, 2001). Their investigation is to outline the repair works for the tunnel and to determine how exactly the damage occur so that it can become a reference for similar cases in the future. In the investigation, it is well agreed that the damage of the tunnel is caused by nearby excavation.

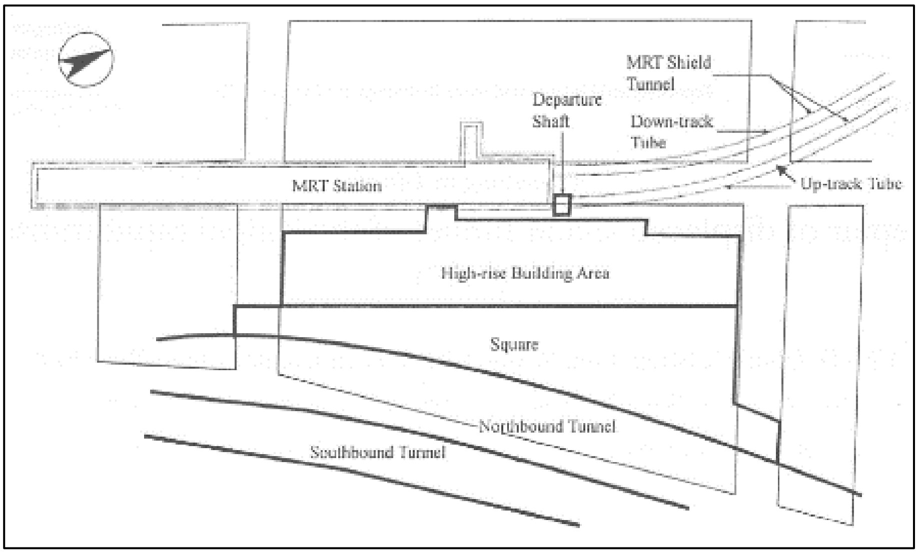


Figure 2.17: Taipei deformed MRT Tunnel (Chang and Wang, 2001)

2.5.4 Demolition

Demolition works is tearing-down of buildings and other structures manually or using hydraulic equipment, a wrecking ball, or a blasting method. Demolition can cause vibration related risk such as:

(i) Excessive vibration generated by demolition works using the blasting method could damage the Railway Infrastructure.

(ii) Demolition works could generate debris or objects that could be projected onto the Railway Infrastructure causing damage.

2.5.5 Use of explosives and fireworks and the lighting of fires

The restricted work includes using explosive materials, fireworks and lighting of fires for any purpose, including blasting, demolition, removal of rocks, or construction. Based from the regulation, the potential risks are:

(i) An explosion or a fire within the Railway Protection Zone could damage the Railway Infrastructure and disrupt Railway Operations.

(ii) Vibration generated from the use of explosives could damage the Railway Infrastructure and disrupt Railway Operations.

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