NOISE STUDY ON MRT INFRASTRUCTURE CONSTRUCTION

MOHAMAD RAHIMIE BIN REMAN

A thesis submitted in
fulfillment of the requirement for the award of the
Degree of Master of Science in Railway Engineering

Centre of Graduate Studies
Universiti Tun Hussein Onn Malaysia

JANUARY 2015

ABSTRACT

Noise is one of the most persistent physical contaminant in human environment. Especially in the developed countries, the technological development and the growth of population are key factors in the increase of noise pollution. According to the Occupational Safety and Health Administration (OSHA), noise is one of the most common health hazards in the construction industry. As stated by Ballesteros *et al.*, (2010), noise is one of the most important acoustic pollutants in the nowadays society, as it is present in most of people's activities; consequently, not only the workers of certain sectors, but all the citizens, are exposed to high noise disturbances. In order to study the noise criteria in MRT infrastructure construction, some parameter should be included. The study included the measurement of noise level at Bukit Bintang MRT Station and Kajang MRT construction site. In addition, the actual level of noise measurement is compared with the theoretical permissible noise based on existing predetermined guideline and standards. Later, the noise criteria for selected construction activites related to railway construction project have been proposed. Sound Level Meter (SLM) was used to measure the noise level for selected site that proposed by Land Public Transport Commission (SPAD). The measurement shows that the ambient noise of this site exceeded the limitation provided by Malaysian Department of Environment, (2007). For the commercial area especially at the Bukit Bintang MRT construction site, 78.84dB was recorded at the distance of 23m from the noise source. For the critical noise level, the noise level for deep excavation work was 88.92dB at the 1^{st} 3m whereas the noise level for the bore piling work was 92.54dB at the 1^{st} 1m. Based on the survey, Bukit Bintang MRT station has the highest noise pollution due to the busiest traffic in the city.

ABSTRAK

Bunyi adalah salah satu pencemaran yang berterusan dalam persekitaran manusia. Terutamanya di negara-negara maju, pembangunan teknologi dan pertumbuhan penduduk adalah faktor utama dalam peningkatan pencemaran bunyi. Menurut Pentadbiran Keselamatan dan Kesihatan Pekerjaan (OSHA), bunyi adalah salah satu hazard kepada kesihatan yang normal dalam industri pembinaan. Seperti yang dinyatakan oleh Ballesteros *et al*, (2010) bunyi adalah salah satu daripada pencemaran yang penting dalam masyarakat sekarang ini, kerana ia wujud dalam kebanyakan aktiviti manusia; akibatnya, bukan sahaja pekerja di sektor-sektor tertentu, tetapi semua rakyat, terdedah kepada gangguan bunyi bising yang tinggi. Dalam usaha untuk mengkaji kriteria bunyi dalam pembinaan infrastruktur MRT, beberape parameter perlu disertakan. Kajian ini adalah untuk mengukur tahap bunyi di Stesen MRT Bukit Bintang dan tapak pembinaan MRT Kajang. Di samping itu, tahap sebenar pengukuran bunyi dibandingkan dengan bunyi yang dibenarkan berdasarkan teori garis panduan dan piawaian yang telah ditetapkan. Kemudian, kriteria bunyi bagi aktiviti pembinaan yang dipilih berkaitan dengan projek pembinaan keretapi telah dicadangkan. Meter Aras Bunyi (SLM) telah digunakan untuk mengukur tahap bunyi tapak pembinaan terpilih yang telah dicadangkan oleh Suruhanjaya Pengangkutan Awam Darat (SPAD). Pengukuran ini menunjukkan bahawa bunyi ambien dari tapak pembinaan ini melebihi had yang diberikan oleh Jabatan Alam Sekitar Malaysia, (2007). Untuk kawasan komersial terutamanya di tapak pembinaan MRT Bukit Bintang, 78.84dB dicatatkan pada jarak 23m dari sumber bunyi. Bagi tahap bunyi yang kritikal, tahap bunyi untuk kerja-kerja pengorekan dalam adalah 88.92dB di 3m pertama manakala tahap bunyi untuk menanggung kerja cerucuk itu 92.54dB di 1m pertama. Berdasarkan kaji selidik, stesen MRT Bukit Bintang mempunyai pencemaran bunyi tertinggi kerana lalu lintas yang paling sibuk di bandar.

CONTENT

CHAPTER 1

INTRODUCTION

1.1 Background of Research

Noise is one of the most persistent physical contaminant in human environment. Especially in the developed countries, the technological development and the growth of population are key factors of the increasing of noise pollution (Fernandez *et al.*, 2009). It is difficult to define what noise means as a physical contaminant. That concept is joined to a subjective perception, and therefore, a sound can be pleasant for some people but, at the same time, can also be annoying for some other people, or even the cause of physical or psychic illnesses. Even more, some sounds that can be acceptable in a certain period of time can change into annoying in other periods (Smith *et al*, 2007).

According to the Occupational Safety and Health Administration, noise is one of the most common health hazards in the construction industry. This hazard is often ignored until the damage is done to person's hearing is severely impaired or completely lost. The ideal way to prevent the adverse effects of noise exposure is to use engineering modifications to the noise source or to the surrounding environment to reduce noise levels. In construction, when activities that produce high levels of noise cannot be altered to acceptable lower noise levels, personal hearing protection must be used. Hearing protection such as ear muffs or plugs should be used by all workers during activities that produce noise levels that may damage their hearing (DOE, Malaysia 2007).

MRT is a mega project initiated by Malaysian government in order to deliver an effective, efficient and integrated mass rapid transit system safely, on time and within cost. The construction of Klang Valley Mass Rapid Transit (KVMRT) still in progress and will become operational in 2016. While Phase Two from Semantan to Kajang will become operational by July 2017, allowing trains to serve the entire line. During the construction works, there are many equipments and machinery used to construct the infrastructure which includes viaduct and tunnels for the MRT lines. This equipment will eventually generate noises which cause some annoyance disturbance to the resident nearer construction site (MRT Corporation 2011).

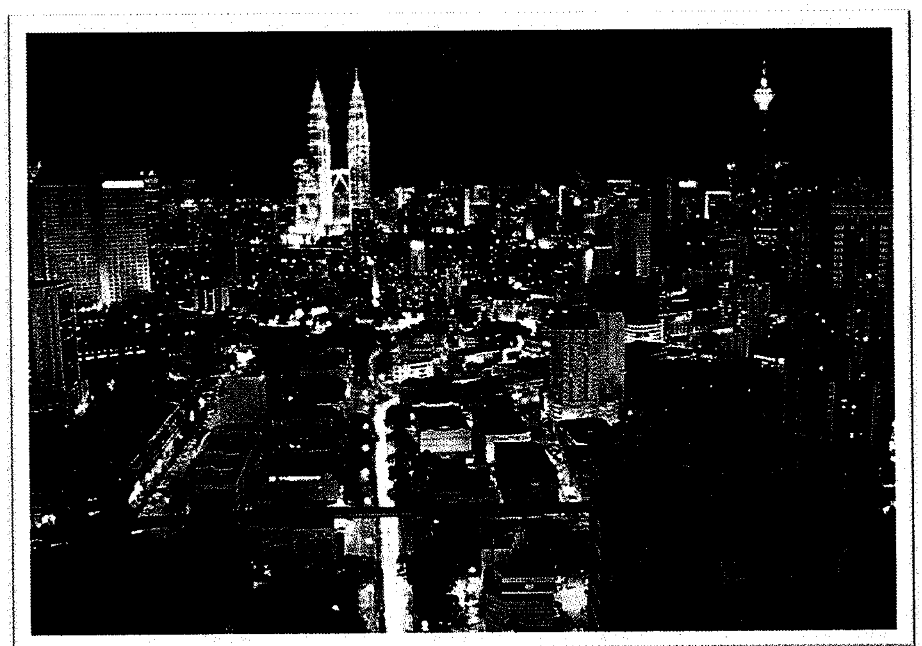

Figure 1.1: Development in Kuala Lumpur

1.2 Problem Statement

The development in Malaysia are increasing rapidly, especially in the infrastructure and building construction. It gives a positive value for a society in Malaysia in creating a comfortable environment and facilities to accommodate the increasing number of people todays. However, the construction work has contributed some bad effects such as noise and vibration disturbance as a result from machine that used in construction work. As stated by Ballesteros *et al.*, (2010), noise is one of the most important acoustic pollutants in the nowadays society, as it is present in most of people's activities; consequently, not only the workers of certain sectors, but all the citizens, are exposed to high noise doses. Hence, a set of political actions regarding that topic has been developed with the aim of decreasing the noise pollution in our environment, creating then, more sustainable cities. These policies point out to the control of traffic noise (by road, train or airplanes), and therefore, laws have been set to establish the methods for assessing and controlling the noise. According to Fernandez *et al.*, (2009), noise exposure can cause several risks for the safety and health of workers. The construction progress generated noise and vibration, which may interfere with the surrounding community, especially in term of emotional and their daily routine, according to BS 5228-2. These guidelines are designed to set the maximum level of noise and vibration that must be followed during construction works to avoid structural damage and also to human disturbance. Besides that, Malaysian DOE also provide The Planning Guidelines for Environmental Noise Limits and Control, (2007). Based on code of practice (Department of Environment & MRT Corporation), the levels of noise generated from construction works were compared. This may helped Land Public Transport Commission (SPAD) & Mass Rapid Transit Corporation in delivering noise minimization strategy on construction practice.

1.3 Objectives

Based on the problems elaborated, the objectives of this study are:

1. To measure the level of noise at Bukit Bintang MRT Station and Kajang MRT construction site.
2. To compare the actual level of noise measurement with the theoretical permissible noise based on existing predetermined guideline and standards.
3. To propose the noise criteria for selected construction activites related to railway construction project.

1.4 Scope of Works

The area for measuring the noise level is for Mass Rapid Transit construction. Collaboration with Malaysia Land Public Transport Commissions (SPAD) was initiated. For this purposes, a meeting with SPAD to propose for research collaboration has been initiated on the 23rd October 2014. The meeting was successful and as the result, a month attachment was agreed and has started on 17th November 2014. Cooperation from the project owner (MRT Corporation) itself was helpful. The selected sites of MRT line construction regarding the noise measuring that proposed by SPAD were at the Bukit Bintang MRT Station and Kajang MRT construction. Sound Level Meter (SLM) has been used to measure the noise during construction operation. The result is presented in decibel, dB and will be compared based on relevant guidelines and standard. In addition, the result is also was compared to the Malaysian Department of Environment, The Planning Guidelines for Environmental Noise Limits and Control, (2007).

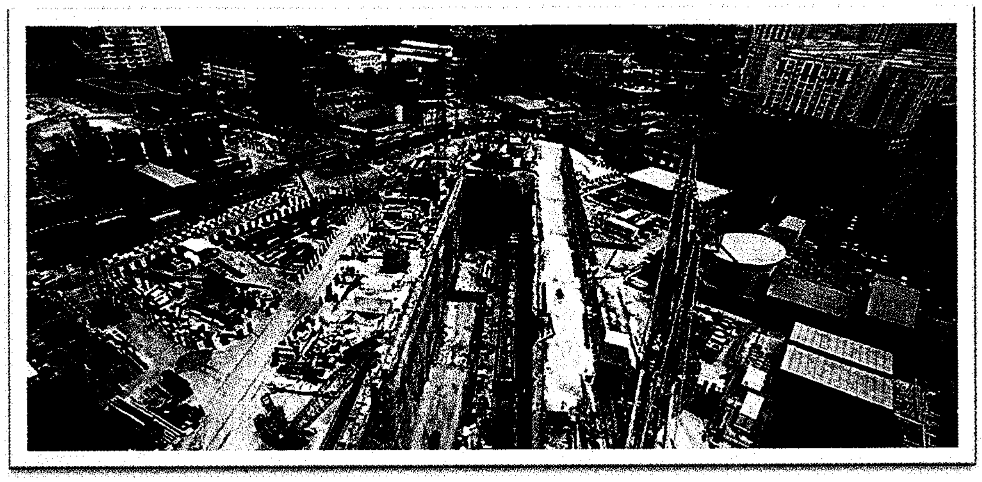

Figure 1.2: MRT Project, Kuala Lumpur (MRT Corporation, 2011)

1.5 Significant of Research

Noise from construction work may cause human annoyance. This study was conducted at Bukit Bintang and Kajang MRT construction which occupies with various human activities nearby.

This study interested in determining the level of noise due to MRT construction works. It is significant to compare the actual level of noise with the theoretical permissible noise based on code of practice (Department of Environment, Malaysia, 2007). Hopefully with this effort may facilitate Land Public Transport Commission (SPAD) & Mass Rapid Transit Corporation in order to reduce the noise impact which is originated from railway construction activity.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, critical information which including findings, theoretical and methodological contributions regarding to the research topic will be included. Literature review on KVMRT construction projects, noise measurement and noise minimization strategy will be explained theoretically. Besides that, previous relevant studies are included.

2.2 KVMRT Construction in Malaysia

The Klang Valley Mass Rapid Transit (KVMRT) project involves the construction of a rail-based public transport network which, together with the existing light rail transit (LRT), monorail, KTM Komuter, KLIA Ekspres and KLIA Transit systems, forms the backbone of the Greater Kuala Lumpur/Klang Valley region. The first MRT line that has been built implemented by the government was the 51km Sungai Buloh-Kajang line. The proposal was for the construction of three MRT lines. The Government conducted a study on the proposal and approved the implementation of the Sungai Buloh-Kajang line first. The Government decided to implement the other two lines after further studies that have been done on the proposed alignment in conjunction with the Greater Kuala Lumpur/Klang Valley Land Public Transport Masterplan being drawn up by the Land Public Transport Commission (SPAD) (MRT Corporation, 2011).

2.2.1 Project Construction

The elevated portion of the MRT Sungai Buloh-Kajang alignment is divided into eight guide way work packages while the underground works come under one work package. With the award of all the guide way and depot contracts, as well as the underground works package, construction activity has progressed. Figure 2.1 shows for main contract packages awarded status and Table 2.1 for the contractors and their respective work packages (MRT Corporation, 2011).

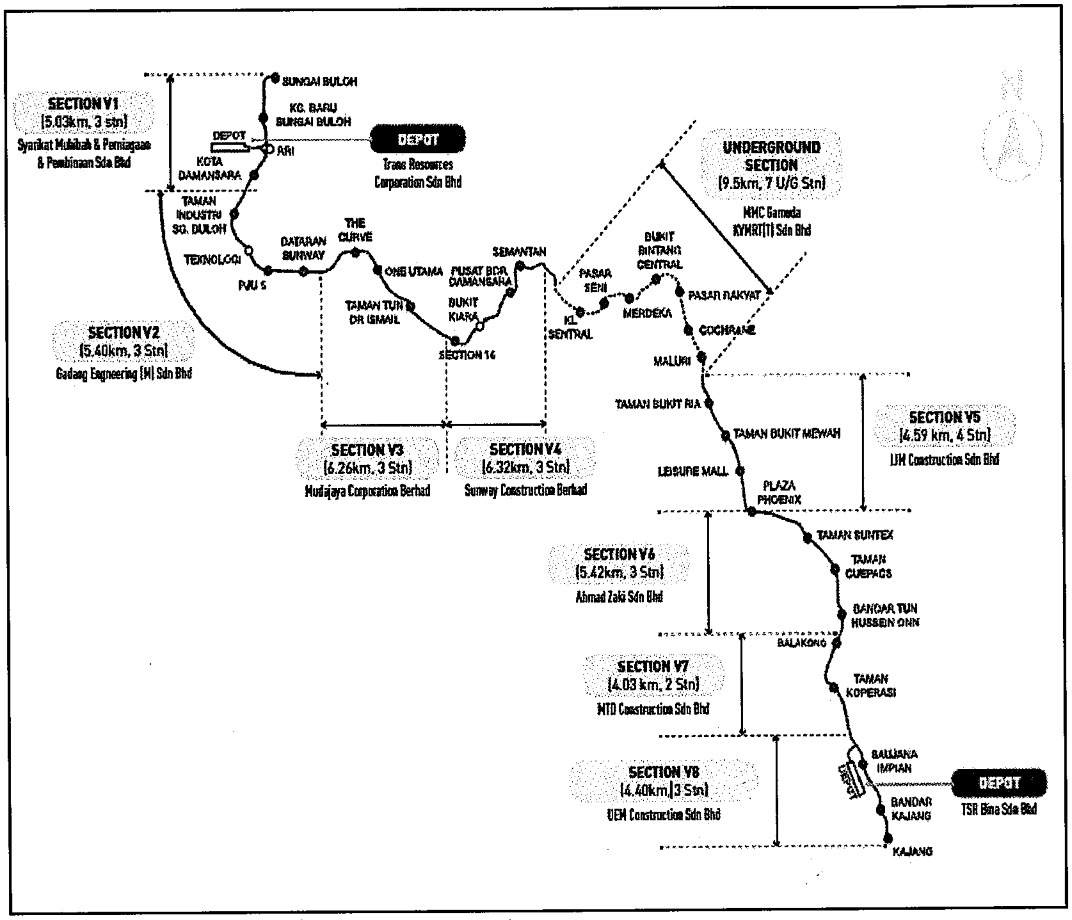

Figure 2.1: MRT main contract packages (MRT Corporation, 2011)

The line starts from Sungai Buloh which is located to the north-west of Kuala Lumpur, runs through the centre of Kuala Lumpur, and ends in Kajang, a fast developing town located to the south-east of Kuala Lumpur. The line serves a corridor with the estimated population of 1.2 million people. The line will be located underground for a distance of 9.5km that consist of 31 stations of which seven will be underground. Each train will have four coaches having a total capacity of 1,200 passengers. The daily expected ridership is about 400,000 passengers. The trains are expected to run at an interval of 3.5 minutes at launch (MRT Corporation, 2011).

Table 2.1: Guideways/Stations/Depots awarded packages (MRT Corporation, 2011)

PACKAGE	CONTRACTOR	VALUE (RM PER MILLON)	PACKAGE	CONTRACTOR	VALUE (RM PER MILLON)
V1	Syarikat Muhibah Perniagaan & Pembinaan Sdn Bhd	1,092.33	S1	Trans Resources Corporation Sdn Bhd	283.67
V2	Gadang Engineering (M) Sdn Bhd	863.39	S2	Naim Engineering Sdn Bhd	204.67
V3	Mudajaya Corporation Berhad	816.24	S3	UEM Construction Sdn Bhd	275.78
V4	Sunway Construction Sdn Bhd	1,172.75	S4	Naim Engineering Sdn Bhd	208.15
V5	IJM Construction Sdn Bhd	974.78	S5	IJM Construction Sdn Bhd	228.91
V6	Ahmad Zaki Sdn Bhd	764.91	S6	Ahmad Zaki Sdn Bhd	174.64
V7	MTD Construction Sdn Bhd	499.98	S7	Apex Communication Sdn Bhd	104.75
V8	UEM Construction Sdn Bhd	951.09	S8	Apex Communication Sdn Bhd	251.74
DPT 2	Trans Resources Corporation Sdn Bhd	458.98	SBG-N	SPC Industries Sdn Bhd	223.18
DPT 2	TSR Bina Sdn Bhd	212.81	SBG-S	Eastern Pretech (M) Sdn Bhd	185.91

2.2.2 Underground Works in the MRT Sungai Buloh-Kajang Line

A 9.5km stretch of the MRT Sungai Buloh-Kajang Line when it traverses the city centre of Kuala Lumpur will be underground. The northern end of the MRT tunnel is at the Semantan Portal at Jalan Duta opposite Parliament House while the southern end of the tunnel is at the Maluri Portal near the Sri Sabah Flats in Cheras. There will be seven underground stations, namely KL Sentral, Pasar Seni, Merdeka, Bukit Bintang Sentral, Pasar Rakyat, Cochrane and Maluri (MRT Corporation, 2011).

The geological condition of the Klang Valley makes tunnelling beneath Kuala Lumpur extremely challenging. The MRT Sungai Buloh-Kajang Line's underground alignment will cut through 2 different geological formations, namely the Kenny Hill Formation which consist sedimentary rocks such as mudstone, shale, phylite and sandstone, and the Kuala Lumpur Limestone Formation with erratic Karstic features comprising eroded limestone rock beneath a layer of top soil (MRT Corporation, 2011).

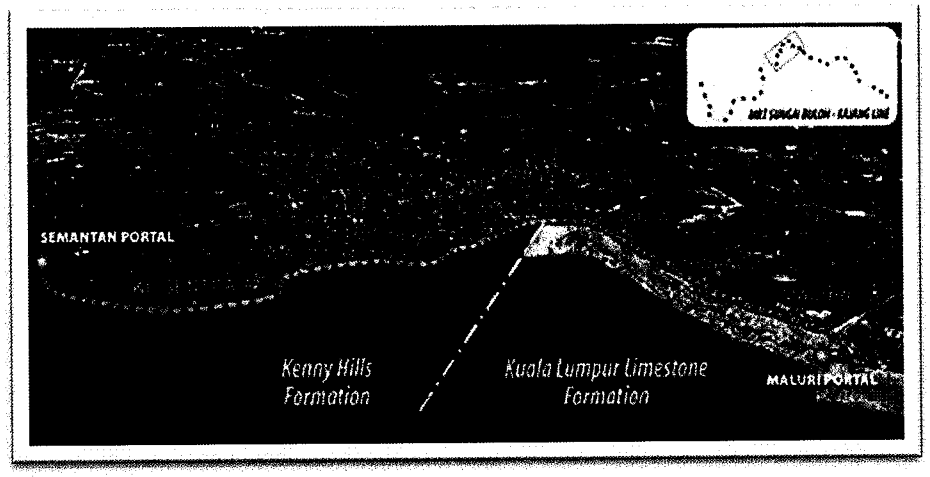

Figure 2.2: The different geological formation under Kuala Lumpur which tunnel boring machines have to excavate through for the MRT tunnel (MRT Corporation, 2011)

To overcome this, meticulous soil investigation work has to done to gather as much information as possible about the soil condition of the tunnel path. On top of that, the correct type of TBM has to be deployed for the correct type of geological formation, and specifically for the Kuala Lumpur Limestone Formation, a special type of tunnel boring machine was developed to overcome the challenges posed (MRT Corporation, 2011).

2.2.3Existing Environment

The SBK Line runs over several geological formations, namely the Kenny Hills Formation, Kuala Lumpur Limestone, Kajang Formation and Granite as shown in Figure 2.3. The alignment from Sg. Buloh station to Pasar Rakyat station is underlain by Granite and Kenny Hill Formation. The stretch from Kota Damansara to Section 17 is underlain by Granite while Section 16 to Bukit Bintang West is underlain by Kenny Hill Formation. Only short stretch from Bukit Bintang East to Pasar Rakyat is underlain by KL Limestone (MRT Corporation, 2011).

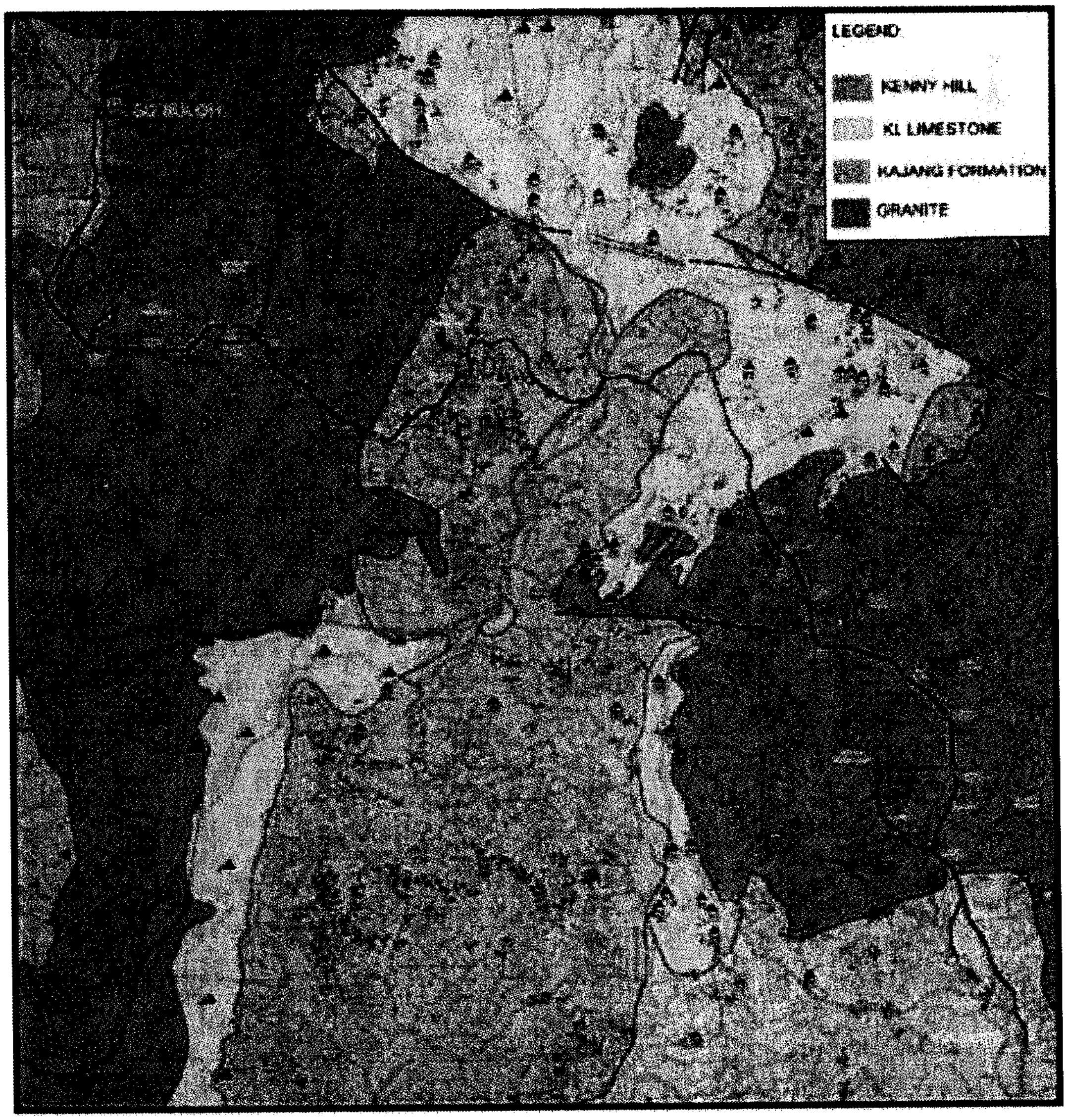

Figure 2.3: Geology underlying SBK line (MRT Corporation, 2011)

The alignment from Pasar Rakyat station to Kajang station is underlain by KL Limestone, Granite and Kajang Formation as shown in Table 2.2. The stretch from Pasar Rakyat to Maluri is underlain by KL Limestone while the Taman Bukit

Ria to Taman Koperasi stretch is underlain by Granite. The remaining stretch from Taman Mesra to Kajang is underlain by Kajang Formation (MRT Corporation, 2011)

Table 2.2: Geology along Sg. Buloh – Pasar Rakyat Station (MRT Corporation, 2011)

Station	Geological Formation
Sg. Buloh	Granite
Kg. Baru Sg. Buloh	Kenny Hill
RRI	Kenny Hill
PJU 5	Granite
Dataran Sunway	Granite
Curve	Granite
One Utama	Granite
TTDI	Granite
Section 17	Granite
Section 16	Kenny Hill
Pusat Bandar Damansara	Kenny Hill
Semantan	Kenny Hill
KL Sentral	Kenny Hill
Pasar Seni	Kenny Hill
Merdeka	Kenny Hill
Bukit Bintang West	Kenny Hill
Bukit Bintang East	Kenny Hill – KL Limestone
Pasar Rakyat	KL Limestone
Cochrane	KL Limestone
Maluri	KL Limestone
Taman Bukit Ria	Granite
Taman Bukit Mewah	Granite
Leisure Mall	Granite
Plaza Phoenix	Granite
Taman Suntex	Granite
Taman Cuepacs	Granite
Bandar Tun Hussein Onn	Granite
Balakong	Granite
Taman Koperasi	Granite
Taman Mesra	Kajang Formation
Saujana Impian	Kajang Formation
Bandar Kajang	Kajang Formation
Kajang	Kajang Formation

The land use along the SBK Line consists of residential, commercial, industrial, institutional and recreational uses. From Sg. Buloh Station – RRI Station, the land use is mainly industrial and commercial. As the SBK Line enters Kota

Damansara, the land use along the SBK Line becomes predominantly residential and remains so until TTDI. After TTDI, the SBK Line follows Jalan Damansara, Leburaya SPRINT and Jalan Semantan where the land use is mainly commercial (MRT Corporation, 2011).

2.2.4 Noise at MRT Alignment

24-hour noise level monitoring carried out at 18 locations from 26th July -20 August 2010 and 1 December 2010 - 30 December 2010 Table 2.3. Most of measured noise levels exceeded the recommended limits for suburban residential area (55dBA for daytime and 45dBA during night time) and urban residential area (60dBA during daytime and 50dBA during nighttime) except for Station N10 (Jalan Bukit Ledang) and Station N11 (Damansara Height) (MRT Corporation ,2011).

Table 2.3: Measured Noise Levels (MRT Corporation, 2011)

Location	Time	Noise Level dBA		
		Leq	L10	L90
Pangsapuri Cempaka, Seksyen 6, Kota Damansara	Daytime	68.4	71.1	68.8
	Night time	63.2	66.6	54.9
Jalan Camar, Seksyen 4, Kota Damansara	Daytime	75.4	78.2	67.1
	Night time	69.5	72.2	57.0
Pelangi Damansara Condominium	Daytime	69.9	71.8	66.4
	Night time	65.2	68.0	58.8
Jalan Aminudin Baki, TTDI	Daytime	71.9	73.6	69.4
	Night time	67.8	70.4	62.7
Pinggiran Zaaba, TTDI	Daytime	65.7	67.3	63.7
	Night time	64.7	67.0	60.6
Jalan SS20/10 Damansara Utama	Daytime	62.2	64.1	59.1
	Night time	59.2	61.9	53.6
Jalan 17/52, PJ	Daytime	63.9	65.8	60.5
	Night time	59.8	61.6	54.8
Jalan Medang Serai, Bukit Bandaraya	Daytime	60.2	62.4	55.8
	Night time	53.0	54.6	48.4
Jalan Jelutong, Taman Damansara Endah	Daytime	61.0	62.2	59.1
	Night time	54.0	56.4	49.2
Jalan Bukit Ledang, K.L	Daytime	51.9	53.4	49.6
	Night time	49.6	50.9	47.5
Jalan Bukit Kota, Bukit	Daytime	57.0	58.1	47.8

Damansara	Night time	50.1	51.1	45.2
Jalan Desa Aman 2, Taman Desa Aman	Daytime	71.8	73.6	69.2
	Night time	69.7	71.9	66.0
Jalan Cerdas, Taman Connaught	Daytime	67.0	69.1	63.4
	Night time	64.0	66.2	57.9
Jalan Sri Kiambang, Taman Sri Raya, Cheras	Daytime	63.1	64.4	60.7
	Night time	59.4	61.6	55.3
Jalan Dewan, Batu 9 Cheras	Daytime	62.6	65.2	59.0
	Night time	60.6	62.8	57.3
Jln Psrn Cuepacs,Tmn Koperasi Cuepacs	Daytime	55.9	58.4	51.5
	Night time	55.0	57.1	52.1
Masjid Sg Sekamat, Kajang	Daytime	66.2	70.4	52.3
	Night time	53.3	69.2	48.5
Jalan 37, Kajang (near stadium Kajang)	Daytime	58.9	62.0	52.9
	Night time	50.9	50.5	56.2

2.3 Noise Regulations

According to the Department of Environment, Malaysia (2007), noise limits may be set based on either depending on an absolute limit based on the average level of noise which should not be exceeded in a specified time period or a relative limit based on the permitted increase in noise level with respect to the background level. These limits may either be a single value over the relevant time periods, or different values for day and night.

Table 2.4 prescribes maximum permissible sound level (LAeq) by receiving land use for planning purposes and new development. These limits should be used for new industrial, commercial or housing areas; and/or development affecting such areas. Such limits are deemed to be a requisite in protecting public health and welfare with an adequate margin of safety (DOE, Malaysia, 2007).

Table 2.4: Limiting sound level (Laeq) for railways including transits (For new development and re-alignments) (DOE, Malaysia, 2007)

Receiving Land Use Category	Day Time 7.00 am – 10.00 pm	Night Time 10.00pm -7.00 am	Lmax (Day & Night)
Noise Sensitive Areas Low Density Residential Areas	60 dB	50 dB	75 dB
Suburban and Urban Residential Areas	65 dB	60 dB	80 dB
Commercial, Business	70 dB	65 dB	80 dB
Industrial	75 dB	65 dB	NA

According to Railway Association of Canada and the Federation of Canadian Municipalities, (2013), the rail noise issue is site-specific in nature, as the level and impact of noise varies depending on the frequency and speed of the trains, but more importantly, the impact of noise varies depending on the distance of the receptor to the railway operations. The distance from rail operations where impacts may be experienced can vary considerably depending on the type of rail facility and other factors such as topography and intervening structures.

Figure 2.4 shows typical transit and non-transit sources of noise .Per cent Highly Annoyed (%HA) is an indicator developed by Health Canada to assess the health implications of operational noise in the range of 45 - 75 dB. It is suggested that mitigation should be proposed if the predicted change in %HA at a specific receptor is greater than 6.5% between project and baseline noise environments, or when the baseline-plus project-related noise is in excess of 75 dB (Railway Association of Canada and the Federation of Canadian Municipalities, 2013).

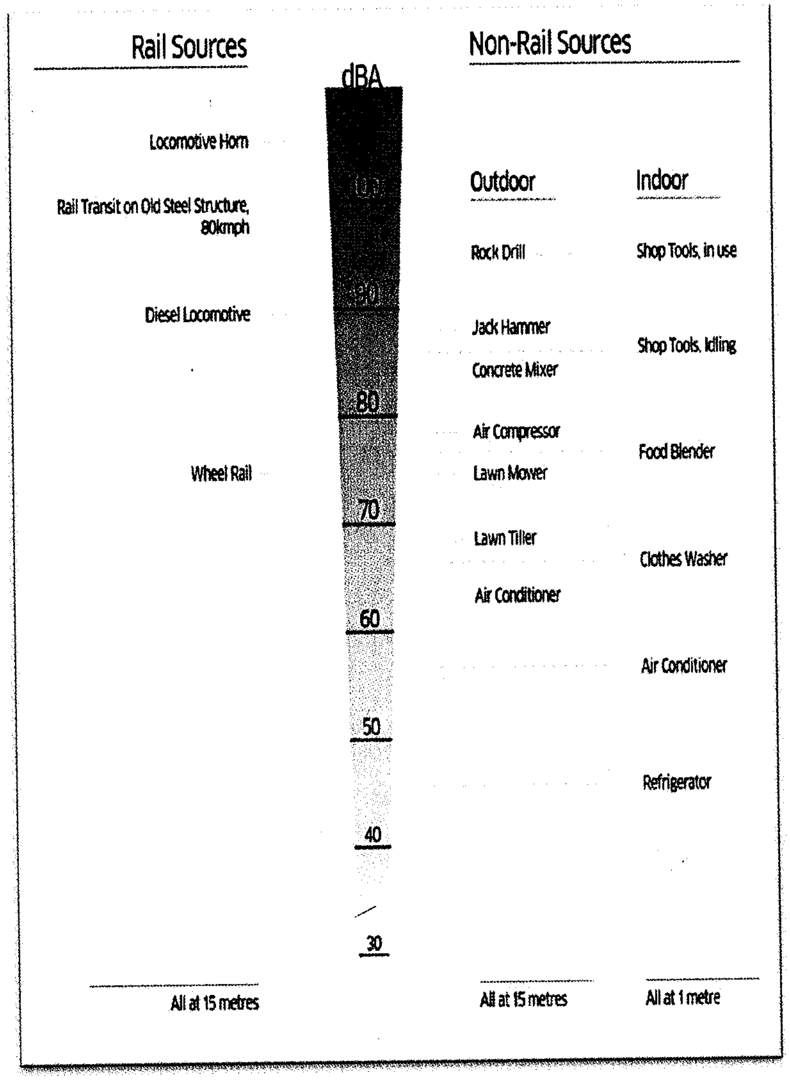

Figure 2.4: Typical transit and non-transit sources of noise (Railway Association of Canada and the Federation of Canadian Municipalities, 2013)

National Environment Agency regulates noise at construction sites using a set of maximum permissible noise limits. Noise limits are set for different times of the day and night and the limits also vary according to the sensitivity of the affected premises. The use of prescribed noise limits allows the construction industry to adopt innovative solutions to minimise the noise disturbances rather than a blanket ban on construction work (Khairul Sani, 2012).

Table 2.5 Permissible Noise Limits (Khairul Sani, 2012)

Mondays to Saturdays			
Type of affected buildings	7am- 7pm	7pm – 10pm	10am – 7am
a)Hospitals, schools, institutions of higher learning, homes for aged sick, etc	60 dBA (Leq 12hrs)	50 dBA (Leq 12hrs)	
	75 dBA (Leq 5 mins)	55 dBA (Leq 5 mins)	
b)Residential buildings located less than 150m from contruction site	75 dBA (Leq 12hrs)	65 dBA (Leq 1hrs)	55 dBA (Leq 1hrs)
	90 dBA (Leq 5 mins)	70 dBA (Leq 5 mins)	55 dBA (Leq 5 mins)
c)Buildings other than those in (a) and (b) above	75 dBA (Leq 5 mins)	65 dBA (Leq 5 mins)	
	90 dBA Leq 5 mins)	70 dBA (Leq 5 mins)	

Sundays and Public Holiday			
Type of affected buildings	7am- 7pm	7pm – 10pm	10am – 7am
a)Hospitals, schools, institutions of higher learning, homes for aged sick, etc	60 dBA (Leq 12hrs)	50 dBA (Leq 12hrs)	
	75 dBA (Leq 5 mins)	55 dBA (Leq 5 mins)	
b)Residential buildings located less than 150m from contruction site	75 dBA (Leq 12hrs)	-	-
	75 dBA (Leq 5 mins)	55 dBA (Leq 5 mins)	55 dBA (Leq 5 mins)
c)Buildings other than those in (a) and (b) above	75 dBA (Leq 5 mins)	65 dBA (Leq 5 mins)	
	90 dBA Leq 5 mins)	70 dBA (Leq 5 mins)	

2.3.1 Maximum Daily Noise Exposure

As people respond differently to noise, the level at which noise will start causing damage is unknown. The amount of damage caused by noise depends on the total amount of energy received over time. A 3 dB(A) increase in noise level will produce twice the energy output and cause the same damage in half the time. Figure 2.5 shows different exposure for different sound levels when all equivalent to exposures of 85 dB(A) for eight hours (Government of South Australia, 2008).

For example, two minutes of working in noise levels of 109 dB(A) may cause the same damage as eight hours working in 85 dB(A). Long periods of repeated exposure to workplace noise levels between 75 dB(A) and 80 dB(A) present a small risk of developing a hearing disability. As noise levels increase, the risk becomes greater. For example, exposure to noise levels of 85 dB(A) to 90 dB(A) presents a considerably greater risk of a developing hearing disability. The acceptable noise exposure standard in the workplace is 85 dB(A) averaged over an eight-hour period. This is not to imply that below 85 dB(A) a safe condition exists. It simply means that an eight-hour exposure of 85 dB(A) is considered to represent an acceptable level of risk to hearing health in the workplace. Impulse noise levels in excess of the peak exposure standard of 140 dB(C) are considered to be hazardous and capable of causing immediate hearing damage (Government of South Australia, 2008).

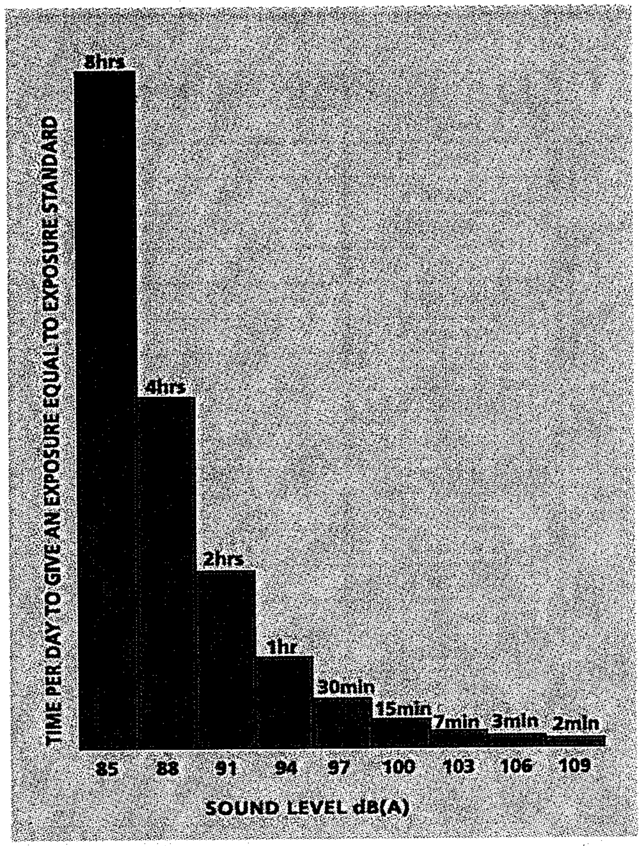

Figure 2.5: The different exposure times for different sound levels (Government of South Australia, 2008)

Whether standard exposure of 85 dB(A) averaged over eight hours is exceeded depends on the level of noise involved and how long workers are exposed to it. Peak noise levels greater than 140 dB(C) usually occur with impact or explosive noise such as sledge-hammering or a gun shot. Any exposure above this peak can create almost instant damage to hearing. Table 2.6 below demonstrates the length of time a person without hearing protectors can be exposed before the standard is exceed (Safe Work Australia, 2011).

Table 2.6: Equivalent Noise Exposures (Safe Work Australia, 2011)

Noise Level dB(A)	Exposure Time
80	16 hours
82	12 hours
85	8 hours
88	4 hours
91	2 hours
94	1 hours
97	30 minutes
100	15 minutes
103	7.5 minutes
106	3.8 minutes
109	1.9 minutes
112	57 seconds
115	28.8 seconds
118	14.4 seconds
121	7.2 seconds
124	3.6 seconds
127	1.8 seconds
130	0.9 seconds

2.4 Effect of Noise to Health

One of the major elements for the normal conduct of human activities by day, evening and night is acoustic comfort noise defined by maintaining the recommended parameters. Due to the on-going momentum of daily activities, noise is one of the most influential factors of stress, which leads to increased fatigue and disturbance in the human activities. For this reason it can be considered as one of the negative "side effects" of civilization. The tendency for the formation of large urban areas results in increasing the number of noise sources, something that is emphasized especially in areas adjacent to traffic arteries and industrial activities (Stephen *et al.*, 2003).

According Stephen *et al.*, (2003), noise exposure during sleep may increase blood pressure, heart rate and finger pulse amplitude as well as body movements. There may also be after-effects during the day following disturbed sleep; perceived sleep quality, mood and performance in terms of reaction time all decreased following sleep disturbed by road traffic noise.

According Department of Environment, Malaysia, (2007), exposure to high noise levels for unprotected ears can be a serious hazard to health, causing permanent damage to hearing. Noise can contribute to both temporary and permanent hearing loss. However current evidence suggests that the risks at the typical exposure levels associated with environmental noise are very low. Noise induced hearing loss often occurs at higher frequencies first, at around 4000 Hz. Hearing damage can then extend to lower frequencies and become relatively more severe after increasing exposure at higher levels. Temporary hearing loss after short term exposure may be associated with permanent hearing loss even though the physiological mechanisms may be quite different. Noise induced hearing loss can directly contribute to increased stress and annoyance, particularly in respect of speech communication and tasks requiring auditory cues. There are of course many other potential or contributory causes of hearing loss in any particular case including illness, ototoxic drugs, hereditary factors and inflammation of the middle ear (Nicole *et al.* 1998).

2.4.1 Noise on Construction Sites

The National Institute for Occupational Safety and Health (NIOSH) estimates that approximately 30 million workers are exposed to hazardous noise on the job. There are many different sound levels that workers are exposed to through the various phases of construction projects. When these sound levels become elevated for an extended duration, it may cause permanent hearing damage. As sound levels become elevated and undesirable, they are typically referred to as noise. When adequate protection and proper training is not implemented, noise can do significant damage to human ear resulting in hearing loss.

According to Occupational Safety and Health Administration, noise is one of the most common health hazards in the construction industry and it is also often been ignored unless the damage occurred a person's hearing is severely impaired or completely lost. The ideal way to prevent the adverse effects of noise exposure is to use engineering modifications to the noise source or to the surrounding environment to reduce noise levels. In construction, when activities that produce high levels of noise cannot be altered to acceptable lower noise levels, personal hearing protection must be used. Hearing protection such as ear muffs or plugs should be used by all workers during activities that produce noise levels that may damage their hearing (Kontarbinska, 2009).

2.4.2 Noise Exposure to Workers

Fernandez *et al.*, (2008) studied noise exposure to the construction worker. A number of representative measurements have been carried out using a sound level meter and a dosimeter to collect data from workers devoted to different tasks in the construction process. The daily equivalent A-weighted level is shown in the chart of the Figure 2.6. It clearly shows that most of the workers suffer a daily exposure that exceeds 80 dBA. This is the lower limit that implies an action according to the current regulation. However, 20 out of 40 workers or 50.0%, exceed 87 dBA in which is the top limit. The workers that have been experiencing more than 90 dBA said explicitly that they needed machines for their tasks. On the other hand, those who exposed with levels below 85 dBA hardly ever used machines while working day (Fernandez *et al.*, (2008).

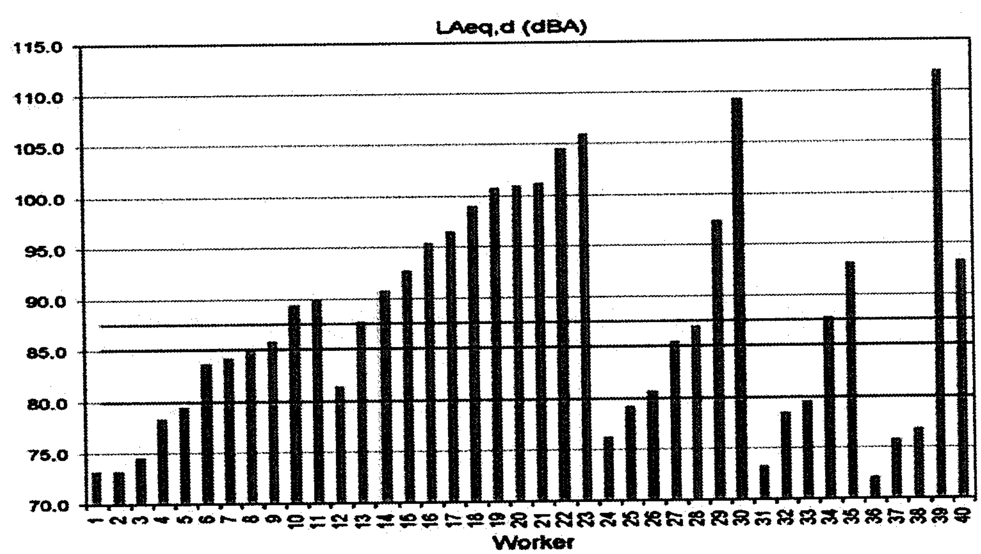

Figure 2.6: Daily equivalent level for each worker measured (Fernandez *et al.*, (2008)

The results Figure 2.7 indicate the average spectrum measured for both sets. Despite the great difference of levels, all the occupations that require machinery have in common that the level increases as the frequency does the same. That is probably due to the fact that most of the machines have their frequency components of noise emission at the high frequency range. On the other hand, the workers that do not require machinery have a spectrum that decays at high frequency.

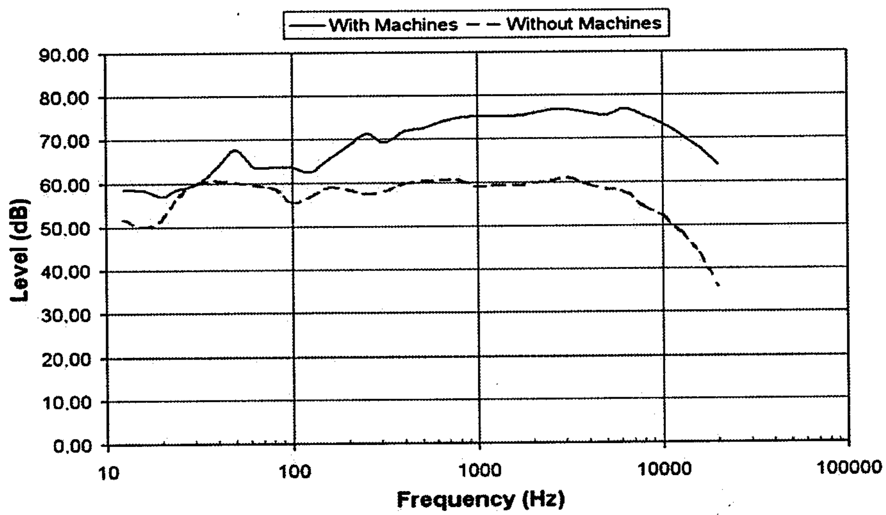

Figure 2.7: Noise spectrum suffered by workers that must use machines for their tasks and by workers that scarcely use machines for their tasks (Fernandez *et al.*, (2008)

2.4.3 Hearing Loss in Construction

Hearing impairment has become a common hazard in the industry. This is due to elevated noise levels being so prevalent in the construction industry and the common lack of hearing protection use, The National Institute for Occupational Health and Safety, United State, (NIOSH), predicts that approximately 30 million United States construction workers are exposed to hazardous noise and over 10 million will damage their hearing as a result. Damage to hearing in the construction industry is commonly referred to as noise-induced hearing loss (NIHL). Noise-induced hearing loss (NIHL) is defined as loss of hearing secondary to over-stimulation by sound energy (Seidman, 1999). According to Occupational Safety and Health

Administration, occupationally induced hearing loss is one of the leading occupational illnesses in the United State Chronic NIHL is a permanent sensor neural condition and cannot be treated medically (Dunn, 2001). Workers that are exposed to elevated noise levels do not realize that noise does more than compromise hearing. In addition to its effects on hearing, noise interferes with understanding speech, causes stress, interferes with sleep, lowers morale, reduces efficiency, causes annoyance, interferes with concentration and causes fatigue. (Dunn, 2001). Noise can also cause tinnitus, a constant ringing sound in the ear, as well as increased blood pressure and stress that may lead to heart disease (Center to Protect Workers' Rights, CPWR, 2003).

There have been a number of studies on NIHL in the construction industry. Several of these studies were conducted to find various sources of elevated noise levels and the consequences associated with prolonged noise exposure. Others were conducted to see if the workers were aware of the problem (Dunn, 2001).

NIHL is the leading cause of occupationally induced hearing loss in industrialized countries (Dunn, 2001). Noise that reaches an elevated level of 85 decibels for an extended period of time may cause a person to experience a temporary or permanent shift in that individual's temporary threshold. A temporary threshold shift (TTS) is a momentary reduction in hearing that typically occurs after a person is exposed to a short period of loud noise such as a jet engine or loud music. One may experience a temporary ring in the ears, but there is usually a full recovery within a few hours. In contrast, a permanent threshold shift (PTS) is an irrecoverable impairment in hearing and occurs after a longer and higher intensity sound exposure. It is generally accepted that the more intense and greater duration of noise exposure, the greater the hearing loss (Dunn, 2001).

2.4.4 Noise of Construction Works

According to Ballesteros *et al.*, (2009), the average spectrum of all the stages is quite similar, except for the excavation stage. This has higher levels and a bigger dependence on the machinery used. The other four stages analysed have only little

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