SUPERSTRUCTURE CONSTRUCTION ACTIVITIES' OCCUPATIONAL NOISE EXPOSURE

NORIHAN BINTI MOHD MOHAIDIN

A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Construction Management)

School of Civil Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

JANUARY 2020

ACKNOWLEDGEMENT

First of all, Alhamdullilah and praises to ALLAH the Almighty, the most benevolent and the most Merciful, for giving me the utmost strength to have this thesis completed.

I would like to thank to Dr. Zaiton Binti Haron for all her attentions, guidances, advices, assistance, encouragement and supports given to my project. Under her care and well supervision towards this project had helped me to complete this project on time. And not to forgotten to my family especially to my husband, Mohd Ariffuddin Bin Ramli and my mother, Mashitah Binti Mohd Yusof for all advices and support that they give me to throughout this project.

Not forgetting to all my friends MKAM Ipoh and the other lecturers who contributed to this project. Their knowledge, sharing and support as well as positive critics give some inspiration to complete this project. Thank you so much and my sincere appreciation.

ABSTRACT

Malaysia currently undergoes an excessive development phase for achieving developed country in the year 2020, thus construction activities play a major role in achieving Malaysia's target. However, construction is the key factor in noise pollution. Noise is an undesirable sound that can lead to an industrial hazard if the occurrence is excessive, and eventually will bring a negative impact on the health and safety of living things if the exposure is of the limit from the allowable range. Industries of constructions are the main contributor to noise pollution, especially from the heavy construction field that resulted in complained by a society that noise produced disturbing the residential area from having a peaceful time. Hence, the worst situation for construction workers who are the most exposed with a high noise level that will risk their health with diseases such as loss of hearing ability, hypertension and irregular heartbeat if no awareness and undertaken of precaution executed. Unfortunately, Malaysia is facing with least availability of data related to noise from construction machines and workers exposure level especially during superstructure stage, although records from The Social Security Organization (SOCSO) shows that many construction workers had seek for compensation due to hearing impairment.Therefore, this study is done mainly to evaluate the occupational noise exposure of construction workers due to superstructure stage activities. To obtain this aim, symptom on hearing loss among workers were acquired through questionnaire and followed by the measurement of sound intensity produced by construction machineries widely used. The measurement of occupational noise exposure on-site was then determined. Sound power level of machineries were determined according to ISO 112000, Acoustics-Noise emitted by machinery and equipment while noise exposure was measured according to Factories and Machinery Act 1967 (Act 139) P.U. (A) 1/89 Factories and Machinery (Noise Exposure) Regulations 1989. The results show that the symptom of hearing loss does exist when it was found that 39% of workers with more than 15 years of working in constructions continuously suffering hearing interruption when they need to communicate at a distance of more than one meter. Also, there were machineries at superstructure stage that potentially susceptible to noise-induced Hearing Loss to construction workers such as Pneumatic Drill / Hacker, Bar Bending, and Dump Truck as they produced high sound intensity more than 85 dBA. Further, Backhoe and Dump truck operators were obtained to have highest mean of time weighting average (TWA) of 80 dBA. According to FMR 1989, this value is not causing the noise-induced hearing loss. However, there were operators have TWA values exceed 85 dBA in which the management team should be aware of. There was also correlation between TWA and sound power level of machineries and its age. The older the age of the machines, the higher noise will be producing by machine.

ABSTRAK

Pada masa ini Malaysia mengalami proses pembangunan yang semakin meningkat untuk mencapai tahap negara maju pada tahun 2020, oleh itu aktiviti pembinaan memainkan peranan utama dalam mencapai sasaran tersebut. Walau bagaimanapun, pembinaan adalah faktor utama dalam pencemaran bunyi. Kebisingan adalah bunyi yang tidak diingini, yang boleh mengakibatkan bahaya kepada industri jika berlaku secara berlebihan dan akhirnya akan mendatangkan kesan negatif terhadap kesihatan dan keselamatan penduduk persekitarannya jika pendedahan itu melebihi daripada julat yang dibenarkan. Industri pembinaan adalah penyumbang utama kepada pencemaran bunyi, terutamanya melibatkan pembinaan berskala besar yang mengakibatkan orang ramai mengeluh tentang bunyi bising yang mengganggu ketenteraman kawasan kediaman. Oleh itu, keadaan terburuk bagi pekerja pembinaan adalah siapa yang paling banyak terdedah dengan tahap hingar yang tinggi akan membahayakan kesihatan mereka dengan penyakit seperti kehilangan keupayaan pendengaran, tekanan darah tinggi dan degupan jantung yang tidak teratur. Ianya boleh berlaku jika tiada sebarang kesedaran dan langkah berjaga-jaga dilaksanakan. Malangnya, Malaysia menghadapi kekurangan data yang berkaitan dengan bunyi bising daripada mesin pembinaan dan tahap pendedahan pekerja terutamanya semasa peringkat superstruktur, walaupun rekod daripada Pertubuhan Keselamatan Sosial (PERKESO) menunjukkan bahawa ramai pekerja pembinaan telah meminta pampasan akibat gangguan pendengaran. Oleh itu, keutamaan kajian ini dilaksanakan untuk menilai tahap pendedahan bunyi bising pekerja-pekerja binaan akibat daripada aktiviti superstruktur. Untuk mendapatkan matlamat ini, gejala kehilangan pendengaran di kalangan pekerja diperolehi melalui soal selidik dan diikuti dengan pengukuran keamatan bunyi yang dihasilkan oleh jentera pembinaan yang digunakan secara meluas. Pengukuran tahap bunyi bising yang dialami oleh pekerja binaan ditentukan. Tahap kekuatan bunyi jentera telah ditentukan mengikut ISO 112000, *Acoustic-Noise* yang dipancarkan oleh jentera dan kelengkapan, sementara pendengaran bunyi diukur mengikut Akta Kilang dan Jentera 1967 (Akta 139) P.U. (A) 1/89 Peraturan Kilang dan Jentera (Pendedahan Bunyi) 1989. Keputusan menunjukkan bahawa gejala kehilangan pendengaran wujud apabila didapati bahawa 39% pekerja yang bekerja lebih dari 15 tahun dalam pembinaan terus mengalami masalah pendengaran apabila mereka perlu berkomunikasi pada jarak lebih daripada satu meter. Selain itu, terdapat jentera di peringkat superstruktur yang berpotensi terdedah kepada kehilangan pendengaran yang disebabkan oleh bunyi bising kepada pekerja-pekerja binaan seperti mesin gerudi, mesin lenturan besi dan lori kerana ia menghasilkan intensiti bunyi yang tinggi lebih daripada 85 dBA. Di samping itu, pengendali *backhoe* dan lori telah memperolehi jumlah purata wajar (TWA) di dalam lingkungan 80 dBA. Menurut FMR 1989, nilai bunyi bising ini tidak menyebabkan kehilangan pendengaran. Walau bagaimanapun, terdapat pengendali mempunyai nilai TWA melebihi 85 dBA di mana pihak pengurusan perlu mengambil kesedaran. Terdapat juga hubungan di antara TWA dan bunyi mesin dan juga usia mesin. Lebih tua umur mesin, bunyi yang lebih tinggi akan dihasilkan oleh mesin.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BB	-	Bar bending machine
BC	-	Bar cutting machine
BH	-	Backhoe
CD	-	UK Current data
CMT	-	Concrete mixer truck
CNS	-	Central nervous system
dB	-	decibels
DOE	-	Department of Environment
DOSH	-	Department of Safety and Health
DT	-	Dump truck
GR	-	Generator
HC	-	Pneumatic drill / hacker
HD	-	UK Historical data
HPDs	-	Hearing protection devices
MC	-	Mobile crane
MD	-	Malaysia data
NIHL	-	Noise-induced hearing loss
NIOSH	-	National International Occupational Safety and Health
NIP	-	Net installed power
NRR	-	Noise reduction rating system
SLM	-	Sound level meter
SPSS	-	Statistical package for the social sciences
TWA	-	Time weighted average
WHO	-	World Health Organisation

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

Malaysia is currently in a phase of developing for urbanization and massive constructions are in a process of undergoing to ensure the Malaysia government is capable to allocate a higher income to the nation in the year 2020 after all the effort striving towards developed country successfully reached. However, a big risk is about to be bared, as construction activity contribute to the main source for noise pollution, due to the level of sound emitted, that capable to influence on health of livings after considering the oscillation of frequency which were high, pressure level released that also high and noise produced were variation, compared to other generation of noises from activities, such as moving vehicles, operating factories, public works, earthworks, and air traffic. Therefore, it is essential to understand in the field of constructions in order to overcome the noise problems by construction activities.

Constructions are dealing with activities including development of buildings, reconstruction of landscapes and assembles of infrastructures which require the usage of huge vehicles, gigantic machineries, and heavy tools, in order to be able to execute heavy works such as transporting huge and heavy items, demolition works, preparation works, structure fabrication works, repair works and even maintenance work, hence construction workers or also known as contractors are people who responsible in handling all type of this heavy equipment. Unfortunately, these big sizes of transportations, machinery and tools will produce sounds with high decibels that can exceed the range of human hearing frequency. Therefore, contractors are the most exposed to the noise pollution hazards. Some of the noises can be handled but some are inevitable that only can be controlled by better work practices.

That is answering, why is it vital for the person in charge of safety to understand and apply the practical steps as well to be aware of all reasonable activities to mitigate the noise pollution effects. Constructions also covering activities at the site of indoors, outdoors and even both. Besides that, work functions and activities during construction will always changing vary on the stage of construction comply with the project timeline allocated. Not only that, the noise level will be produced during construction work which also changing vary on the level of work functions and activities, depends on the type of vehicles, tools, and machinery used. However, the presence of noise will lead to health problems if the person is exposed with a sound at a higher frequency or working too long within the surrounding of noise that possibly resulting in tinnitus, hearing loss, increase of heart rate, fasten in breathing rate, hypertension, disturbance in sleep, lack in focus, fatigue, and aggression, according to Industrial Noise Control Module, DOSH (2018).

1.2 Background of Problem

Sound can be heard due to the vibration of particles that travel through the air and hits our eardrum. Sounds can be measured by evaluating the sound pressure on a logarithmic scale with a unit of decibels (dB). Meanwhile, noise occurs due to the undesirable sounds that generated, which caused unpleasant and disturbance to the human hearing system due to the level of loudness that cannot be tolerated by people's eardrum. A noise study in Ontario, Canada has reported average sound levels produced during constructions are between 93.1 dBA and 107.7 dBA. Hence, construction activities are responsible for a major production of noise because the vehicles used in construction were designed to transport tons of mass while machinery used for construction was designed to handle huge cubic meters in volume and tools used within construction were designed to withstand with high pressure and hardness. Hence, noise pollution was generated form all equipment of construction, as stated by Sinclaire and Haflidson (1995), the primary source of sound in the construction site is from tools and equipment. Besides that, according to Raymond et al. (1985), noise complaints received in Singapore due to constructions were nearly 18%. Therefore, it is a norm for the construction site to produce noise because it is impossible to achieve zero-noise during works in construction.

However, according to NIOSH (1990), an occupation that dealing with exposure of noise at a high level especially from vehicles, tools, and equipment are facing a great risk in terms of hearing loss and hypertension. Thus, employees and nearby residents are at severe risk to be affected by bad health conditions. Schneider and Tennenbaum (n.d.) had done studies to evaluate on hearing loss among 66 roofing workers, with average age of 20 years old and 40 years old, using questionnaires tool that equipped with information on hazards, such as exposure to vibration, fuel, thinning or solvent, paint, glue, lead, extreme heat, and extreme cold, as well as information on hypertension and shooting habits, and the results from their study found out that workers usually work more than half-day and they mostly not wearing a hearing protection during working hours (2 always, 7 often, 11 sometimes, and 46 never) , hence lead to hypertension and hearing loss (Sinclaire & Haflidson, 1995).

In Malaysia, the guideline for the workplace has been described completely in the Factories and Machinery (Noise Exposure) Regulations 1989 that concern on permissible noise levels and exposure times (FMR, 1989). Therefore, wearing the dosimeter over a complete work shift (for example 8 hours) was introduced as a method to evaluate the average noise exposure by the worker. Noise exposure level should be below 90 dBA and not exceeding 115 dBA at any time. Other than that, it is stated in guidelines for environmental noise by the Department of Environment (DOE), Malaysia and the World Health Organization (WHO) that noise generated from the construction sites must be less than permissible limits (DOE, n.d). The noise level shall be measured using the sound level meter. Superstructure stage of construction in Malaysia dealing with noise during the activities of excavating, drilling, and installing using a variety of machines and equipment either static in one location or moving in the vicinity. Hence, this stage requires quite several workers upon completion of work. Therefore, this study is important to determine the exposure levels of noise during construction at the superstructure stage by machineries that potentially cause a noise-induced hearing loss towards construction workers.

1.3 Problem Statement

The construction industry in Malaysia is massive, unfortunately, noise control is still not to be taken seriously at the construction site and the awareness in the allowable level of noise among the construction workers is still low. According to Nawi et al. (2018), their study showed that 33% of construction workers were exposed to noise levels greater than 90 dBA, which mainly came from machinery that operated at the construction site. This is proven that machinery used in construction are potentially emitting the highest level of noise compared to other machines used for general work or by industries.

Furthermore, in the early 1980s, National International Occupational Safety and Health (NIOSH) had estimated that employees were exposed to noise in various jobs, including construction, were at a level of 85 dBA and above. There were also studies conducted in the 1960s and 1970s that show construction workers have been overexposed to noise. The highest percentage of exposure among employees occurred mostly during the constructions of highways, road, carpentry, and concrete work. Moreover, approximately 5 million workers from the construction field, 754,000 workers had exposed to noise levels of 85 dBA and above in the year 1995 (Suter, 2002).

Studies in the early of years the 1960s and 1970s also have pointed out the problem of noise that caused on hearing threshold faced by worker during the process of construction, but no severe case from the noise exposure by the construction workers recorded until Kenney and Ayer (1975), found that by using more sophisticated audiometric equipment, such as hand-held power tools, 33 construction workers that deal with sheet metal were at a level of hearing threshold. Other than that, LaBenz et al. (1967) has measured on hearing level among 66 operators of earth-moving or mobile vehicles for construction work and found that workers who exposed to noise regularly, had lost their hearing capabilities faster than workers who were rarely exposed to noise regardless a range of age. Hence, the hearing threshold case had shifted, where no longer old people are at a risk from being diagnosed with hearing thresholds but to all people at various ages.

Public Health Service and Health Examination Surveys of 1960-1961 and 1971-1975 has divided industrial workers into three categories which are construction, manufacturing/mining, and others. Next, Waitzman and Smith (1996) has performed a multivariate regression analysis from all groups of industrial workers and found that the construction category showed the highest number of worker suffered from hearing loss at all degrees of severity with involvement of all ages, thus, proven the magnitude of noise caused hearing problem and the problem has raised since before today's construction works. Therefore, the management team of construction plays an important role to control noise exposure among the workers by aware of the level of exposure among the worker while always comply with all the regulations stated by Malaysia law, responsible by NIOSH during the construction activities.

In other word, it is necessary for the person in charge to identify the noise status exposed by the worker which emitted by vehicles, tools, and machinery used during construction work so that consequences faced by construction workers can be determined either exposure experienced was in long term or in short term period at any severe level of noises. Hence, noise exposure conditions experienced by construction workers also can be identified either effecting only the worker or also toward the surrounding. Eventually, solutions to overcome can be taken correctly. However, some developing region in Perak is still lacking with a record of noise data collection from machinery and construction workers respectively, plus limited access to site from September until November of 2019 give difficulty to obtain survey on hearing loss symptom among workers. Furthermore, hard to assess the machineries which potentially cause noise-induced hearing loss (NIHL) among workers plus there are least evaluations of workers' TWA has been recorded.

1.4 Objectives

The aim of this study is to evaluate the level of sound emitted by construction machinery involved during the superstructure stage among construction workers at 5 selected construction sites in Perak either complying with the permitted noise exposure in the construction industry. Hence, this study is carried out to study three important objectives to ensure the aim of this study can be achieved this aim, which are:

1. To obtain the hearing loss symptom among workers during the superstructure stage
2. To assess machineries that potentially cause noise-induced hearing loss (NIHL)
3. To evaluate occupational noise exposure experienced by construction workers

1.5 Scope of Study

This study covers small scale projects of five sites in the state of Perak which are operating under superstructure stage. The data of noise collected were according to the availability of machinery used by the activities performed at representing the site. The study begun with questionnaires, interviews, and surveys distributed among workers to gain primary data of hearing loss symptoms among workers during construction. The session of questioning, interviewing and surveying were conducted in a duration of four weeks. Noise emitted by machinery during the superstructure stage of construction were evaluated using Sound Level Meter Type 2 and correlating between sound power level (Lw) of machineries and machines’ maintenance and age respectively in the order determining the machineries that potentially lead to NIHL. Finally, Personal Noise Dosimeter reading during working hours were used to evaluate TWA followed by correlating the maintenance of machineries and age of machine respectively to see the significance of finding.

1.6 Significant of Findings

The construction field is one of the important elements for the development of Malaysia because buildings and infrastructure connecting people and courage nations to build business among themselves. However, noise produced is highly concerning due to harm to human health, thus noise exposure control needs to be emphasized. One way to improve the existing system of controlling noise in Malaysia is by collecting the information in the source of noise emitted and collected data are to be analyzed in order to answer the raise problems with solutions. It is strongly believed that this study is capable to be a helpful medium in identifying the needs and concerns of the workers in construction field besides sparking the awareness among workers to improve the precaution during working hours as well as to provide a better quality of surrounding during construction in order minimizing the severity of health impact towards the workers.

Furthermore, the questionnaire can provide the reader with valuable information on areas that need to be improved and provide a figure for contractor/private sector/public sector in determining the best solution to be taken in overcoming noise problems. Questionnaires data are important to ensure information regarding noise problem is being aware, hence courage programs such as developing a healthy workplace and surrounding to be executed. Last but not least, this study can serve as a reference for new developer’s team to create a greener construction procedure, develop environmentally-friendly programs and sustainable policies that will improve workers’ health as well as creating a productive and positive work environment.

The level of noise measured from the machinery used by construction activities during the superstructure stage is at least could be as a reference especially for a contractor in identifying the level of noise produced by evaluated machines. The data obtained on the level of noise-exposed among construction workers in Malaysia can be used as proof in supporting claims by NIOSH, especially in the section of occupational noise that resulted in hearing disorders.

REFERENCES

Acoustics. (n.d.). Retrieved from https://www.engineeringtoolbox.com/

After crane crash, Taman Desa residents stage protest against condo development. (2018). Retrieved from Malaymail website: https://www.malaymail.com/news/malaysia/2018/02/03/after-crane-crash-taman-desa-residents-stage-protest-against-condo-developm/1568861

Ali, S. A. (2011). A case study of construction noise exposure for preserving worker's hearing in Egypt. *Acoustical Science and Technology*, *32*(5), 211–215. https://doi.org/10.1250/ast.32.211

Ballesteros, M. J., Fernández, M. D., Quintana, S., Ballesteros, J. A., & González, I. (2010). Noise emission evolution on construction sites. Measurement for controlling and assessing its impact on the people and on the environment. *Building and Environment*, *45*(3), 711–717. https://doi.org/10.1016/j.buildenv.2009.08.011

BSI. (2009). *British Standards Code of practice for noise and vibration control on*.

Ciorba, A., Benatti, A., Bianchini, C., Aimoni, C., Volpato, S., Bovo, R., & Martini, A. (2011). High frequency hearing loss in the elderly: Effect of age and noise exposure in an Italian group. *Journal of Laryngology and Otology*, *125*(8), 776–780. https://doi.org/10.1017/S0022215111001101

Cochran, P., Throop, J., & Simpson, W. E. (1968). Estimation of Distance of a Source of Sound Author (s): Reviewed work (s): Source : The American Journal of Psychology , Vol . 81 , No . 2 (Jun ., 1968), pp . 198-206 Published by : University of Illinoi. *The American Journal of Psychology*, *81*(2), 198–206.

Darus, N., Teknologi, U., Haron, Z., Teknologi, U., Han, M., & Universiti, L. (2015). *Construction Noise Annoyance among the Public Residents Jurnal Teknologi Construction Noise Annoyance among the Public Residents*. *4*(November), 19–26. https://doi.org/10.11113/jt.v74.4604

Davies, H. W., Teschke, K., Kennedy, S. M., Hodgson, M. R., Hertzman, C., & Demers, P. A. (2005). Occupational exposure to noise and mortality from acute myocardial infarction. *Epidemiology*, *16*(1), 25–32. https://doi.org/10.1097/01.ede.0000147121.13399.bf

DEFRA. (2005). *Update of Noise Database for Prediction of Noise on Construction and Open Sites*. Norwich.

Department of Enviroment. (n.d.). *The Planning Guidelines for Enviromental Noise Limits and Control*.

DOSH. (n.d.). *Noise Exposure at Workplace*.

DOSH. (2018). *Industrial Noise Control Module*. *1*(1), 1–66. Retrieved from http://www.dosh.gov.my/index.php/en/industrial-hygiene-ergonomic/pamplet/3026-kawalan-kebisingan/file

DOSH. (2019a). *Industry Code of Practice for Management of Occupational Noise Exposure and Hearing Conservation 2019*.

DOSH, M. (2019b). *OSH (Noise Exposure) Regulations 2019*. (March), 1–26.

Economic Census. (2016). Retrieved from Department of Statistics Malaysia (DOSM) website: https://www.dosm.gov.my/v1/index.php?r=column/ctwoByCat&parent_id=76&menu_id=OEY5SWtFSVVFVUpmUXEyaHppMVhEdz09

Elfaig, A., Duad, M., Adam, N., Bardaie, M., & Abdullah, R. (2016). Monitored Community Noise Pollution in Selected Sensitive Areas of Kuala Lumpur. *International Journal of Scientific & Technology Research*, *3*(2), 10–17.

Factories and Machinery (Noise Exposure) Regulations. (1989). *Incorporating latest amendment - P.U.(A) 106/1989*. (January).

Fernández, M. D., Quintana, S., Chavarría, N., & Ballesteros, J. A. (2009). Noise exposure of workers of the construction sector. *Applied Acoustics*, *70*(5), 753–760. https://doi.org/10.1016/j.apacoust.2008.07.014

Field, M. (1993). Effect of personal and situational variables upon noise annoyance in residential areas. *Journal of the Acoustical Society of America*.

Gannoruwa, A., & Ruwanpura, J. Y. (2007). Construction noise prediction and barrier optimization using special purpose simulation. *Proceedings of the 2007 Winter Simulation Conference*, 2073–2081.

Geetha.M, A. . (2015). Study on impact of noise pollution at construction job site. *International Journal of Latest Trends in Engineering and Technology*, *5*(1), 46–49.

Hamoda, M. F. (2008). Modeling of construction noise for environmental impact assessment. *Journal of Construction in Developing Countries*, *13*(1), 79–89.

Haron, Z., Abidin, M. Z., Lim, M. H., Yahya, K., Jahya, Z., Mohd, S. K., & Saim, A.

A. (2014). Noise exposure among machine operators on construction sites in South Johor, Malaysia. *Advanced Materials Research*, *838–841*, 2507–2512. https://doi.org/10.4028/www.scientific.net/AMR.838-841.2507

Haron, Zaiton, Noh, H. M., Yahya, K., & Majid, Z. A. (2012). Assessing noise emission levels from earthwork construction equipment. *Malaysian Journal of Civil Engineering*, *24*(1), 13–28.

Ismaila, S. O., & Odusote, A. (2014). Noise exposure as a factor in the increase of blood pressure of workers in a sack manufacturing industry. *Beni-Suef University Journal of Basic and Applied Sciences*, *3*(2), 116–121. https://doi.org/10.1016/j.bjbas.2014.05.004

Kantová, R. (2017). Construction Machines as a Source of Construction noise. *Procedia Engineering*, *190*, 92–99. https://doi.org/10.1016/j.proeng.2017.05.312

Kenney, G. D., & Ayer, H. E. (1975). Noise Exposure and Hearing Levels of Workers in the Sheet Metal Construction Trade. *American Industrial Hygiene Association Journal*, *36*, 626–632.

Kolarik, A. J., Moore, B. C. J., Zahorik, P., & Cirstea, S. (2015). *Auditory distance perception in humans : a review of cues , development , neuronal bases , and effects of sensory loss*. (November). https://doi.org/10.3758/s13414-015-1015-1

LaBenz, P., Cohen, A., & Pearson, B. (1967). A Noise and Hearing Survey of Earth-Moving Equipment Operators. *American Industrial Hygiene Association Journal*, *28*, 117–128.

Lee, S. C., Kim, J. H., & Hong, J. Y. (2019). Characterizing perceived aspects of adverse impact of noise on construction managers on construction sites. *Building and Environment*, *152*(February), 17–27. https://doi.org/10.1016/j.buildenv.2019.02.005

Lie, A., Skogstad, M., Johannessen, H. A., Tynes, T., Mehlum, I. S., Nordby, K. C., … Tambs, K. (2016). Occupational noise exposure and hearing: a systematic review. *International Archives of Occupational and Environmental Health*, *89*(3), 351–372. https://doi.org/10.1007/s00420-015-1083-5

Liu, Y., Xia, B., Cui, C., & Skitmore, M. (2017). Community response to construction noise in three central cities of Zhejiang province, China. *Environmental Pollution*, *230*, 1009–1017. https://doi.org/10.1016/j.envpol.2017.07.058

Maintainance Assessment. (n.d.). Retrieved from https://www.plano.gov

Mazlan, A. N., Yahya, K., Haron, Z., Mohamed, N. A., Abdul Rasib, E. N., Jamaludin, N., & Darus, N. (2018). Characteristic of Noise-induced Hearing Loss among Workers in Construction Industries. *E3S Web of Conferences*, *34*, 1–9. https://doi.org/10.1051/e3sconf/20183402025

Middlebrooks, J. C. (1991). *Sound Localization by Human Listeners*. (February 1991). https://doi.org/10.1146/annurev.ps.42.020191.001031

Nachtigall, P. E., Pawloski, J. L., & Au, W. W. L. (2003). Temporary threshold shifts and recovery following noise exposure in the Atlantic bottlenosed dolphin (Tursiops truncatus). *The Journal of the Acoustical Society of America*, *113*(6), 3425. https://doi.org/10.1121/1.1570438

Nawi, N. M., Haron, Z., & Jumali, S. (2018). Regional Conference on Science, Technology and Social Sciences (RCSTSS 2016). In *Regional Conference on Science, Technology and Social Sciences (RCSTSS 2016)*. https://doi.org/10.1007/978-981-13-0074-5

Neitzel, R., Seixas, N. S., Camp, J., & Yost, M. (1999). An assessment of occupational noise exposures in four construction trades. *American Industrial Hygiene Association Journal*, *60*(6), 807–817. https://doi.org/10.1080/00028899908984506

Nipko, K., Madison, O., Shields, C., & Aurora, O. (2003). *Exposure in Construction*.

Pearson’s Correlation Coefficient. (n.d.). Retrieved from Statistics Solution website: https://www.statisticssolutions.com/pearsons-correlation-coefficient/

Quieter Equipment. (2006). Retrieved from Laborers’ Health & Safety Fund of North America website: https://www.lhsfna.org/index.cfm/occupational-safety-and-health/noise/noise-bpg-quieter-equipment/

Raymond, B., Heng, W., & Rao, V. (1985). Construction Noise Standards and The Draft Singapore Code. *Applied Acoustics*, *18*, 337–354.

Rehman, M. Z., Nawi, N. M., & Ghazali, M. I. (2011). Noise-Induced Hearing Loss (NIHL) Prediction in Humans Using a Modified Back Propagation Neural Network. *International Journal on Advanced Science, Engineering and Information Technology*, *1*(2), 185. https://doi.org/10.18517/ijaseit.1.2.39

Report Construction Sites Operating After 10pm. (2018). *Bernama*.

Rowan, D., Papadopoulos, T., Edwards, D., Holmes, H., Hollingdale, A., Evans, L., & Allen, R. (2013). Identification of the lateral position of a virtual object based on echoes by humans. *Hearing Research*, *300*, 56–65. https://doi.org/10.1016/j.heares.2013.03.005

Schneider, S., & Tennenbaum, S. (n.d.). *Hearing Loss Among Roofer. Unpublish Report*. The Center to Protect Workers' Rights, 111 Massachusetts Ave. N.W., Washington, D.C.

Seixas, N. S., Goldman, B., Sheppard, L., Neitzel, R., Norton, S., & Kujawa, S. G. (2005). Prospective noise induced changes to hearing among construction industry apprentices. *Occupational and Environmental Medicine*, *62*(5), 309–317. https://doi.org/10.1136/oem.2004.018143

Shinn-Cunningham, B. (2000). Learning Reverberation: Considerations for Spatial Auditory Displays. *Proceedings of the 2000 International Conference on Auditory Display*, (April), 126--134. https://doi.org/10.1.1.22.5056

Simpson, W. E., & Stanton, L. D. (1973). Head movement does not facilitate perception of the distance of a source of sound. *Amer.J.Psychol.*, *86*(1), 151–159. https://doi.org/10.2307/1421856

Sinclaire, J., & Haflidson, W. C. (1995). Construction Noise in Ontario. *Journal of Occupational and Enviroment Hygiene*, *10*(5), 457–460.

Spencer, E. (2005). Heavy construction equipment noise study using dosimetry and time-motion studies. *19th National Conference on Noise Control Engineering 2005, Noise-Con 05*, *2*, 859–866. https://doi.org/10.1121/1.4781357

Statistik Penyakit dan Keracunan Pekerjaan bagi Jan-Sept 2018. (2018). *Pekerjaan Bahagian Kesihatan*, (September), 1–13.

Survey of Construction industry. (2014). Retrieved from Department of Statistics Malaysia (DOSM) website: https://www.dosm.gov.my/v1/index.php?r=column/ctwoByCat&parent_id=76&menu_id=OEY5SWtFSVVFVUpmUXEyaHppMVhEdz09

Suter, A. H. (2002). Construction noise: Exposure, effects, and the potential for remediation; a review and analysis. *American Industrial Hygiene Association Journal*, *63*(6), 768–789. https://doi.org/10.1080/15428110208984768

Waitzman, N. J., & Smith, K. R. (1999). *Unsound Conditions: Work-Related Hearing Loss in Construction, 1960–1975.* Washington, D.C.

Wallmeier, L., & Wiegrebe, L. (2014). Ranging in human sonar: Effects of additional early reflections and exploratory head movements. *PLoS ONE*, *9*(12). https://doi.org/10.1371/journal.pone.0115363

Wearing Dosimeter. (n.d.) Retrieved from https://www.alliedchemists.com.my/industrial-monitoring/industrial-hygiene-monitoring/noise-exposure-monitoring/

What is Substructure and Superstructure in Building Construction? (2019). Retrieved from The Constructor Civil Engineering Home website: https://theconstructor.org/building/superstructure-substructure-building-construction/1651/

Yoshioka, M., Uchida, Y., Sugiura, S., Ando, F., Shimokata, H., Nomura, H., & Nakashima, T. (2010). The impact of arterial sclerosis on hearing with and without occupational noise exposure: A population-based aging study in males. *Auris Nasus Larynx*, *37*(5), 558–564. https://doi.org/10.1016/j.anl.2010.02.006

Zakaria, W. Z., Majid, M. Z. A., & Nourbakhsh, M. (2012). Developing an Executive Information Site Monitoring System. *Advanced Materials*, *446–449*, 1002–1005.