Noise Exposure Monitoring on the Segmental Box Girder Casting Process from a Concrete Casting Yard

Ming Han Lim, Yee Ling Lee, Ooi Kuan Tan

Abstract*: Noise exposure monitoring is essential to assess noise exposure circumstances and provide a noise control plan to minimize noise exposure problems in the workplace. In Malaysia, occupational noise exposure problems have been increasing, especially in the construction industry. Hence, this study aims to investigate the noise exposure problem in a construction casting yard in Malaysia. The objectives of the study were to measure the current occupational noise exposure problem and to propose a noise control action. Field measurement was carried out at a segmented box girder casting yard under the Mass Rapid Transit (MRT) construction project in Selangor, Malaysia. A total of six case studies from four different construction trades had been conducted. This study plotted noise maps and measured personal noise exposure levels for the three construction trades. The results showed that the equivalent sound level exceeded the action level of 85 dBA for these trades. Besides, the bar cutting trade with an 8-hour time-weighted average of 92.3 dBA exceeded the permissible exposure limit of 90 dBA. The noise reduction rating of the hearing protection device was evaluated, and appropriate noise control action was proposed. The proposed noise reduction rating was 32 dBA, so it is expected to reduce the time-weighted average sound level below 80 dBA for this workplace. In conclusion, the results could disseminate to construction workers to raise their risk awareness regarding the noise exposure issue in the workplace. The noise mapping information could also be used for the design of the engineering control to reduce the noise exposure level in the construction workplace.

Keywords* : *Casting yard, construction noise, noise map, occupational noise exposure

I. INTRODUCTION

One of the primary concerns when it comes to occupational noise is the impact on employees who have prolonged exposure to hazardous noise during the working period. A study conducted in Spanish to identify predictive factors of occupational noise-induced hearing loss (NIHL) [1]. It had found that the duration of exposure to noise and the use of hearing protection as the more significant factors. The results also showed that majority of the respondents who experienced the auditory related symptoms due to prolonged exposure to occupational noise [1]. Two studies showed that the use of the hearing protection device (HPD) among construction workers was deficient despite the compulsory requirement, as stated in local regulation [2]-[3].

According to the Department of Safety and Health Malaysia [4], it had found that 4506 of the cases are of the occupational noise-related hearing disorders. It was about 88 % of the total cases, as reported from January 2018 to September 2018. It has risen about 80 % if compared to the cases reported in 2017. These cases included workers from the construction industry. It proves that workers in Malaysia are lack of awareness on occupational noise and its impact on human health.

The construction industry was one of the industries with the loudest occupational noise level [5]. The Integrated Management Information System (IMIS) data from 1979 to 2006 showed that 62 % of the construction noise samples over the action level of 85 dBA, and 47 % of them exceeded the permissible exposure limit of 90 dBA [6]. Some loud activities over the permissible limit included chipping concrete, demolition, welding, stripping forms, building forms, and wood framing [6]. According to Hong [7], the use of HPD by operating engineers in the construction industry was only at 48 % on average, far less than the 100 % use, as stated in regulations.

Construction equipment and machinery were the primary sources of noise in the construction industry. Among the various type of equipment and machinery, impacting equipment such as pile driver, pneumatic breaker, and pneumatic chipper produce the highest noise level in general. Other construction equipments with average noise higher than PEL were earth moving equipment such as dozer, mobile crane, excavator, and paver [8].

Recent studies plotted the noise maps for construction activities to monitor the excessive noise emitted from the construction machinery [9]-[11]. A noise map could indicate the hazardous noise polluted area and show the pattern of noise distribution to the surrounding areas [12]-[13]. The noise mapping information is vital to gain the awareness of workers towards the impact of noise in their daily working areas. This information could be used for designing the noise control method to cope with the excessive noise in the workplace [14].

Revised Manuscript Received on April 21, 2020.

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This study aims to investigate the noise exposure circumstances in the construction workplace in Malaysia. A concrete casting yard was selected for the study because this workplace involving noisy machinery in operation. The noise maps and personal noise exposure levels were measured as the references for assessing the exposure condition at this workplace. The noise control method was also proposed in this study to reduce the occupational noise exposure problem in the construction workplace.

II. RESEARCH METHOD

In this research, it involved several activities for occupational noise exposure monitoring, such as site investigation, noise mapping measurement, personal noise exposure measurement, data analysis, and noise controlling strategy. The research flow is shown in Fig. 1. This study conducted noise monitoring on a concrete casting yard located at Hulu Langat, Selangor, Malaysia. This yard was casting the segmented box girders for the Mass Rapid Transit (MRT) construction project. The MRT project is one of the mega construction projects in Malaysia.

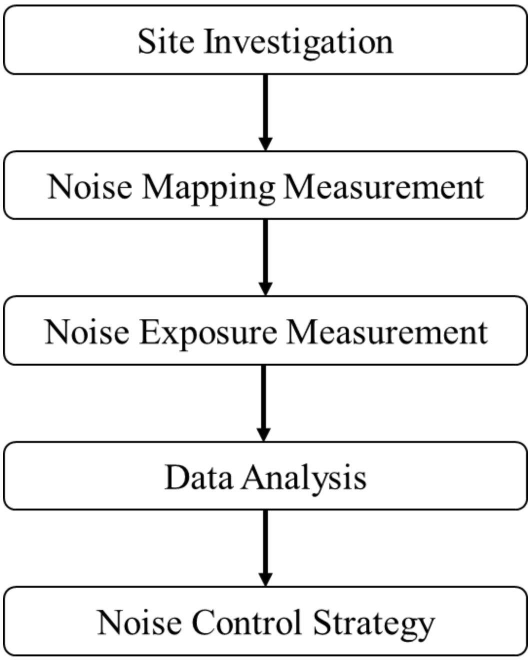


Fig. 1. Research Flow

Initially, this research was carried out a site investigation at the proposed workplace to determine the noise monitoring areas for noise measurement. The noise sources were identified during the investigation. The sequential operation for the activities was also verified. The condition and dimensions of the monitoring areas were recorded before starting the noise measurement. Next, the noise measurement for noise map and personal noise exposure level was measured using the equipment, such as SoundTrack LxT sound level meter. Several noise data were recorded, including noise mapping data, equivalent continuous sound pressure level (L_{Aeq}), maximum and minimum sound levels, and the time-weighted average of sound level (TWA). The L_{Aeq} and TWA could be calculated based on the equations (1) and (2) [15].

The measured data were used to compare with the permissible limit (PEL) as according to the Factories and Machinery (Noise Exposure) Regulations [16]. According to the regulation, the PEL for 8 hours of exposure is 90 dBA. This study also determined the suitable noise reduction rating (NRR) for hearing protection devices as the engineering control method to protect workers from over-exposure to noise. The NRR could be calculated based on equation (3), as recommended from a technical manual [6].

$$L_{Aeq} = 10\log_{10}\frac{1}{N}\sum_{i=1}^{N}10^{\frac{L_i}{10}} \quad (1)$$

where
L_{Aeq} = equivalent sound level, dBA
L_i = sound pressure levels over the periods, dBA
N = total number of average sound pressure levels

$$\text{TWA} = 16.61\log_{10}\frac{D}{100} + 90 \quad (2)$$

where
TWA = Time Weighted Average, dBA
D = noise dose, %

$$\text{EE} = \text{TWA} - [(\text{NRR} - 7) \times 50\ \%] \quad (3)$$

where
EE = estimated exposure, dBA
NRR = noise reduction rating, dBA

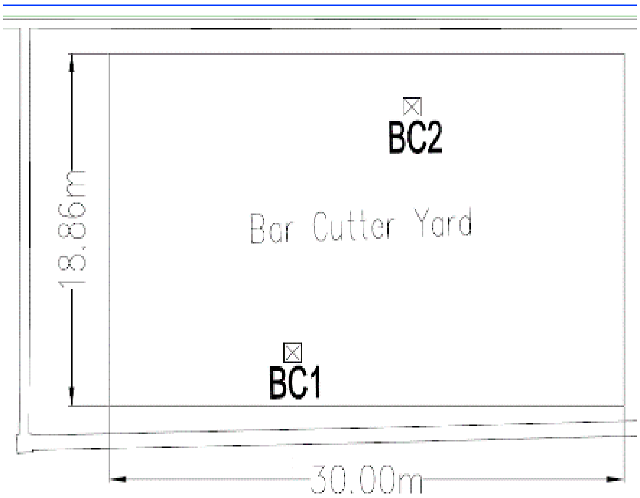
III. NOISE MONITORING AREAS

This study selected the noise monitoring areas based on the locations with hazardous noise sources, and workers were working nearby to the noise source. About three main trades were operating during the segmental box girder casting process, such as bar cutting, bar bending, and concrete casting. The details of the area in concern, such as their layout dimensions and location of sources were recorded. In the bar cutting area, each bar cutting machine is capable of cutting five reinforcement bars of various sizes at once, and emitted high noise level to the surrounding environment. Each of the machines is stationed with four workers, with one of them operating the machine (see Fig. 2a and Fig. 2b). Fig. 2c shows the site layout of the bar cutter yard.

Next, there were three bar bending machines at the site with the labels of BB2 (see Fig. 3a), BB3 (see Fig. 3b), and BB4. Figure 3c shows the site layout of bar bending. Only one worker is working at each bar bending machine. The noise was generated by bending the steel bar and placing the steel bar in the storage area. The number and sizes of reinforcement bar being worked on each bar bending machine varied depending on the orders received. Usually, only one worker is working at each bar bending machine. However, for reinforcement bars of more substantial size, which are heavier, one worker is in charge of the operation of the machine while the other transfer the reinforcement bars around. These bar bending machines are located in the bar bending yard at about 7 m away from each other.

(a)

(b)

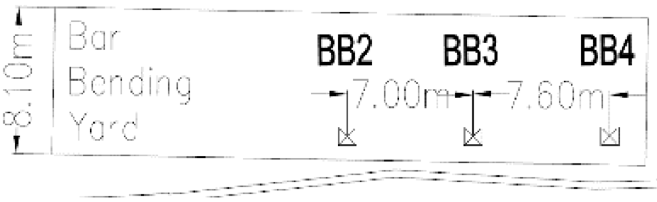


(c)

Fig. 2. Noise Monitoring Area in Bar Cutting Trade: (a) Bar Cutting Machine, (b) Work Operation, and (c) Site Layout.

(a)

(b)

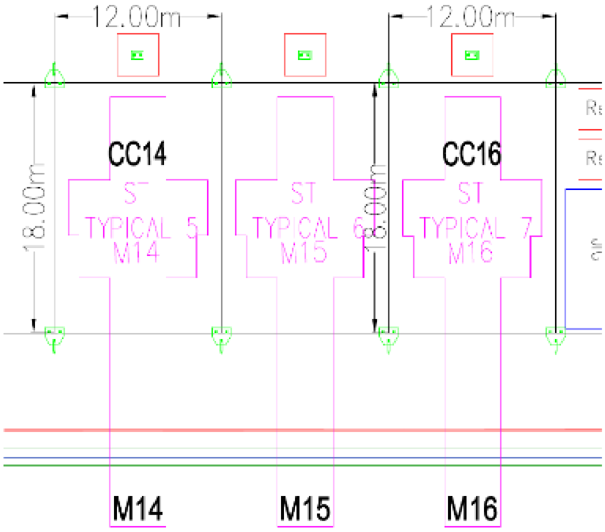


(c)

Fig. 3. Noise Monitoring Area in Bar Bending Trade: (a) Bar Bending Station BB2, (b) Bar Bending Station BB3, and (c) Site Layout.

(a)

(b)



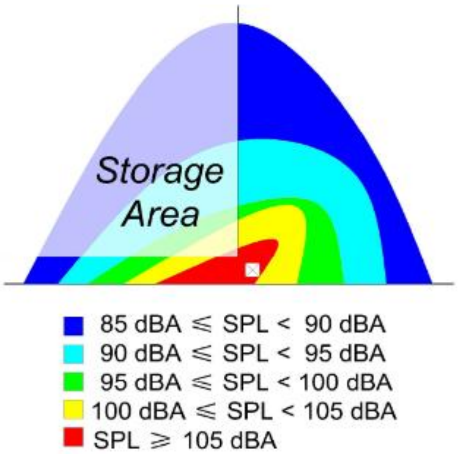
(c)

Fig. 4. Noise Monitoring Area in Concrete Casting Trade: (a) Concrete Casting Mould Station, (b) Operation of Immersion Concrete Vibrator, and (c) Site Layout.

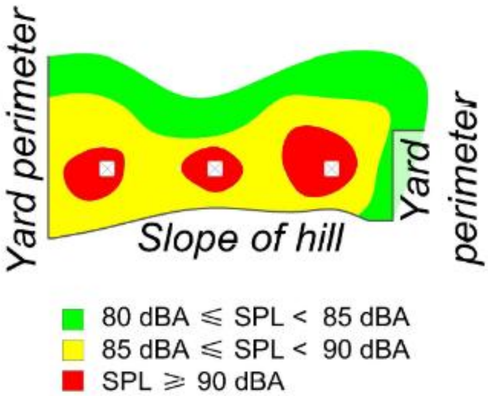
There were more than sixteen concrete casting mould stations in this casting yard. The noise was generated from the concrete casting operation at two concrete casting mould stations during the measurement, and the concrete casting mould site layout of CC14 and CC16 as shown in Fig. 4c. Multiple noise sources were found during the formwork installation activity in concrete casting mould areas, such as transferring of concrete mould, installation of bolts, clearing of debris, and welding. Fig. 4a shows the segmental box girder casting mould. Concrete casting operation generated the noise from the process of concrete vibrators, overhead crane and, concrete truck. There were a total of five workers at a concrete casting mould station during its operation, with one of them controlling the operation of the vibrators, and another four in charging of concrete pouring and operation of the immerse vibrators. Fig. 4b shows the vibration activity after the fresh concrete poured into the casting mould.

IV. RESULT AND DISCUSSION

The noise maps for three different construction trades at the site are illustrated in Fig. 5. It was found that bar cutting machine produced noise exceeding the PEL, 90 dBA within a distance of 9.6 m on average during its operation. As the workers working at the bar cutting station generally work within 3 m radius around the bar cutting machine, they were exposed to noise exceeding 115 dBA, as shown in Fig. 5a. The operator of the bar cutting machine experienced the highest noise exposure as he was close to the bar cutting machine. Similar results had been shown in a study in the United Kingdom, where the reinforcement workers at a construction site have an average sound exposure level of 95 dBA [8].



(a)



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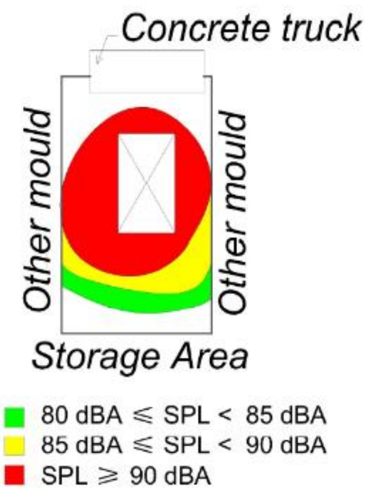

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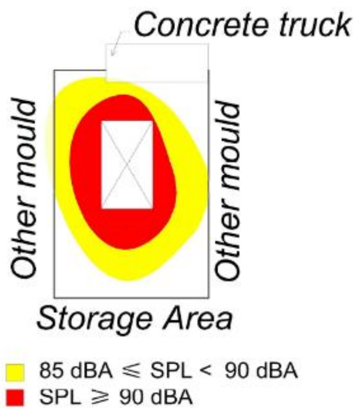

(d)

Fig. 5. Noise Zones, Such as (a) Bar Cutting, (b) Bar Bending, (c) Concrete Casting Mould CC14, and (d) Concrete Casting Mould CC16 Areas.

For bar bending trade, the workers operating the bar bending machine were exposed to noise exceeding the PEL, where the area of averagely 1.95 m radius around the bar bending machines had a sound exposure level of 90 dBA. The noise maps constructed for both concrete casting moulds showed that the workers working at an average of 5.2 m away from the concrete casting mould had noise exposures exceeding the PEL. Similar results had been demonstrated in the previous study where the reinforcement and concrete casting workers at a construction site have exceeded the noise exposure level of 90 dBA [8].

The noise map constructed for both concrete casting moulds showed that the workers working at an average of 5.2 m away from the concrete casting mould had noise exposures exceeding the PEL. Although results showed exceedance of PEL, the readings are lower compared to the average sound exposure levels of 94.5 dBA and 97 dBA for the operator of poker vibrators and concrete pourer respectively, as shown in the previous study [8]. The reason might be due to two casting activities operated non-concurrently during the measurement. It is expected that higher noise levels will be emitted when all casting activities operate concurrently. So, more precaution actions should be taken in this area to prevent workers' from health problems accidents due to exposing a noisy working environment.

Table 1 depicts the exposure of equivalent, maximum, minimum, and TWA sound levels, noise dosage, noise reduction rating, and adjusted TWA sound levels. The bar cutting 2 sample was having the highest noise exposure while the concrete casting sample has the least among the six samples. For the 8-hour TWA, only the bar cutting 2 showed exceedance of the permissible limit of PEL, 90 dBA. Different value of 8-hour TWA for Bar Cutting 1 was obtained due to the sizes and number of reinforcement bars being cut during the monitoring.

During the monitoring, it was observed that the larger the size of the reinforcement bars and the number of bars being cut, the higher the noise created.

Although the personal noise exposure results indicated the bar cutting trade as a hazardous activity, the management still requires monitoring the noise exposure level carefully in other trades as the noise zones have shown the hazardous areas for these trades. The results show that all monitored areas exceeded the PEL and possess relatively high noise exposure risk when working in this area.

For the noise control strategy, this study proposes the provision of hearing protectors, such as earplugs, for the workers whose exposure exceeded the PEL at their workplace. The highest result from Bar Cutting 2 activity was used as the reference in the design to standardise the type of earplug used in the workplace. The target 'in-ear' noise exposure level was set to be reduced to below 80 dBA. Workplace Health and Safety Queensland [17] mentioned that good attenuation of exposure level should be within the range of 75 dBA to 80 dBA. According to the Health and Safety Executive [18], it set the 'in-ear' noise exposure level below 85 dBA. Therefore, the proposed NRR was 32 dBA to reduce the TWA sound levels below 80 dBA, as shown in Table 1.

Table- I: Personal Noise Exposure Based on Different Trades.

Trades	L_{Aeq} [dBA]	L_{Amin} [dBA]	L_{Amax} [dBA]	TWA [dBA]	Dose [%]	NRR [dBA]	Adjusted TWA [dBA]
Bar Cutting 1	90.4	63.3	105.7	85.0	50.3	32	72.5
Bar Cutting 2	94.7	77.5	108.8	92.3	137.7	32	79.8
Bar Bending 1	88.4	70.0	103.4	81.4	30.5	32	68.9
Bar Bending 2	86.0	69.3	98.2	71.2	7.4	-	71.2
Formwork Installation	87.3	70.0	100.9	77.6	18.0	-	77.6
Concrete Casting	81.9	62.6	99.4	63.9	2.7	-	63.9

Observation at the site during the noise monitoring showed that none of the workers was equipped with any form of HPD. Upon further inquiry, it was found that HPDs were provided, but the workers did not wear them regularly for a few reasons. These reasons include discomfort to the wearer, inconvenience in communication, as well as the inability to hear warnings in the forms of yell or shout. This reason concurs with the study in Spain [19] in which the lack of usage of HPD depends on the willingness of workers. In order to overcome this issue, the results of this research can be disseminated to the workers by their supervisors to increase their awareness regarding the actual noise exposure they experience at work as well as the impact of it. The noise information helps the workers to identify the hazardous noise exposure area [11]. Workers will take preventive actions when they could self-perceive the noise risk in their workplace.

V. CONCLUSION

In conclusion, the concrete segmental box girder casting process consists of high noise exposure risk. This study had conducted noise monitoring on three main trades, including bar cutting, bar bending, and concrete casting. The noise exposure levels in the monitoring areas have exceeded the PEL of 90 dBA. Among the three main trades, the bar cutting trade was found with the highest exposure risk as the TWA sound level exceeded the limits. This study proposed the provision of HPD to the workers as the noise control strategy in this workplace. The HPD should have at the NRR at least 32 dBA to reduce the exposure level below 80 dBA. The management should always supervise their workers on the usage of HPD regularly when exposed to the hazardous areas in this workplace. By the way, the results of this study can be disseminated to the construction workers to increase their awareness of the issue of occupational noise exposure and to reduce the impact of occupational noise exposure to them.

Several recommendations were made for the improvement and extension of future study on a similar topic, as shown below:

1. Study the workers' behaviours after the dissemination of the results of this project to observe for changes in workers' attitudes towards HPD. For example, observations can be made on the number of workers who start wearing HPD, as well as the correctness of how the HPD is used.
2. Increase the number of samples for the construction of noise zones as the representability of the noise zone for the particular construction trade can be increased by the consistency from multiple samples.
3. Propose other forms of noise control action such as engineering control that reduces the production of noise itself and administrative control, which typically reduce the noise exposure to workers by limiting their time spent in a noisy area. A comparative study could be conducted on these methods to rectify the most effective and efficient method to be used in the construction industry.
4. Audiometric test, which assesses the hearing ability of test subjects, can be conducted to explore the impact of occupational noise exposure based on the employee individually instead of via trade-based noise monitoring.

ACKNOWLEDGMENT

Authors would like to thank Universiti Tunku Abdul Rahman for providing financial support (UTARRF Vot no. 6200/L08) in this research. The authors would like to express the deepest gratitude to Tan Kai Xin for her assistance in this research.

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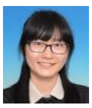

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