AUTOMATED CONSTRUCTION NOISE PREDICTION BY CONSIDERING THE VARIABILITY OF NOISE SOURCES AND OUTDOOR SOUND PROPAGATION

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Especially for my beloved parents Jahya Bin Markom and Hamidah Bte Abd Kadir and my family....

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ABSTRACT

Noise has become a serious concern due to increase of construction development. Continuous exposures to excessive noise result in physical, physiological and psychological effects. To reduce these effects, the prediction of noise from construction in the early planning stage is suggested. In Malaysia, the prediction is based on the BS5228: Part 1: 2009 procedure. However, the equivalent noise level (L_{Aeq}) prediction from BS5228 was claimed to be inaccurate, and previous research suggested that the primary solution is to predict noise using stochastic approach. Nonetheless, the predictions of noise using stochastic approach were not carried out in a detail manner and not all factors that may affect the noise were considered. Therefore, this study further investigates the accuracy of the noise prediction by using BS5228 procedure, followed by improving the method of noise prediction using stochastic approach and develops an automated model for noise prediction. Among considered factors include the variability of position and height of the sources, as well as receiver and variability of outdoor sound propagation. The automated model was designed using MATLAB's Graphical User Interface (GUI) and produced equivalent continuous sound level, L_{Aeq}, standard deviation and other parameters of noise levels such as L_{10}, L_{90} and L_{max}. The accuracy between measured and predicted noise levels was measured using statistical tests in SPSS (Statistical Package for Social Science) software and also using MAPE (Mean Absolute Percentage Error) method. The result of t-test showed significant difference between L_{Aeq} obtained from measurement and BS 5228 procedure. Meanwhile, the comparison of L_{Aeq} between measurement and simulation was insignificant throughout t-test and overall, the results from MAPE method were also in the acceptable range. As a conclusion, noise prediction using Monte Carlo approach can be used as the alternative way in predicting noise from construction.

ABSTRAK

Bunyi menjadi perhatian serius berikutan peningkatan pembangunan pembinaan. Pendedahan yang berterusan kepada bunyi bising yang berlebihan mengakibatkan kesan fizikal, fisiologi dan psikologi. Untuk mengurangkan kesan-kesan ini, ramalan bunyi bising di peringkat perancangan awal pembinaan adalah disyorkan. Di Malaysia, ramalan bunyi bising adalah berdasarkan kaedah BS5228: Part 1:2008. Walau bagaimanapun, tahap bunyi setara (LAeq) ramalan dari BS5228 didakwa tidak tepat , dan penyelidikan terdahulu mencadangkan bahawa penyelesaian utama adalah dengan meramalkan bunyi menggunakan pendekatan stokastik. Walau bagaimanapun, ramalan bunyi menggunakan pendekatan stokastik tidak dijalankan secara terperinci dan tidak semua faktor-faktor yang boleh memberi kesan bunyi yang dipertimbangkan. Oleh itu, kajian ini mengkaji ketepatan ramalan bunyi dengan menggunakan kaedah BS5228 , diikuti dengan menambahbaik kaedah ramalan bunyi menggunakan pendekatan stokastik, dan membangunkan model automatik ramalan bunyi. Antara faktor-faktor yang dipertimbangkan termasuk kepelbagaian kedudukan dan ketinggian sumber bunyi serta penerima dan kepelbagaian penyerapan bunyi luaran Model automatik direka menggunakan *Graphical User Interface* (GUI) dan menghasilkan aras bunyi setara, L_{Aeq} , sisihan piawai dan parameter lain tahap bunyi seperti L_{10} , L_{90} dan L_{max} . Ketepatan diantara aras bunyi setara yang dicerap dan diramalkan telah diuji dengan menggunakan ujian statistik dalam perisian SPSS (*Statistical Package for Social Science*) dan juga menggunakan kaedah MAPE (*Mean Absolute Percentage Error*). Hasil ujian-t menunjukkan terdapat perbezaan yang signifikan antara L_{Aeq} diperolehi dari cerapan dan prosedur BS 5228 . Manakala, perbandingan antara L_{Aeq} cerapan dan simulasi adalah tidak signifikan melalui ujian-t dan keseluruhannya keputusan daripada kaedah MAPE juga dalam julat yang boleh diterima. Sebagai kesimpulanya, ia menunjukkan bahawa ramalan bunyi menggunakan pendekatan Monte Carlo boleh digunakan sebagai kaedah alternatif dalam meramalkan bunyi bising dari pembinaan.

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LIST OF SYMBOLS

L_p	=	Sound pressure level
L_w	=	Sound power level
L_{Aeq}	=	Equivalent continuous sound level
$L_{Aeq5min}$	=	Sound level equivalent for 5 minutes
L_{Aeq30s}	=	Sound level equivalent for 30 seconds
L_{max}	=	Maximum sound level
L_N	=	Percentile Levels
L_{10}	=	Percentile levels with values exceeding 10% of elapsed time
L_{50}	=	Percentile levels with values exceeding 50% of elapsed time
L_{90}	=	Percentile levels with values exceeding 90% of elapsed time

LIST OF ABBREVIATION

DOE	=	Department of Environment
dB(A)	=	Decibel
SPL	=	Sound pressure level
CDF	=	Cumulative Distribution Function
PDF	=	Probability Distribution Function
MAPE	=	Mean Absolute Percentage Error
GUI	=	Graphical Interface User

CHAPTER 1

INTRODUCTION

1.1 Introduction

Malaysia has been a successful developing country which has undergone rapid infrastructural development. There are many new construction and reconstruction of the building such as residential, commercial building and others. A significant and adverse effect on this continuing development is the increase in the level of the noise pollution, particularly in the vicinity of construction sites. According to Zolfagharian *et al*. (2012), it was determined that noise pollution was the most risky environmental impact on construction sites in Malaysia. Excessive noise from the construction site can give adverse effect to the workers and the surrounding community, such as hazard to physical health, communication and social life activities. Generally, noise produced from construction site is mainly from plants, heavy equipments and machinery.

Noise from construction activities is the common problem everywhere and the most important fact that cannot be eliminated. However, it can be reduced by a good management of noise especially in the early planning. The first step to reduce the noise level is the prediction of noise in the early planning. The prediction indicates the probability of noise level generated from construction sites during working hours. Thus, consultant, contractor, workers and authorities can get early information about the possibility of noise generated from the construction sites, and then the investigation of noise elimination can be done before construction activities are carried out. The prediction in the early planning is very important to avoid serious effect of noise to the workers and the surrounding community during the construction. Therefore, the appropriate method to predict noise level generated from construction sites is required to give the accurate prediction of noise emission.

1.2 Background of Study

Continuous exposure to excessive noise may result in physical, physiological and psychological effects including hearing loss, cardiovascular problem, mental illness and annoyance. In order to reduce these effects, the prediction of construction noise in the early planning stage is suggested. In Malaysia, the prediction of noise proposed by Department of Environment is based on the BS5228: Part 1 (Noise Control on Construction and Open Sites). The prediction should be made at an early planning by planner, developers, architects, engineers and environmental health officers to avoid excessive noise level. The method of noise prediction by using BS5228 only calculates the equivalent continuous A-weighted sound level L_{Aeq} and considered as the deterministic approach which results in only a single output. This method also assumes certain factors that may influence the noise level at the receiver such as meteorological factors, ground surface attenuation, screening and reflection as a gross simplification. Thus, the prediction by using BS5228: Part 1 is claimed as inaccurate. Haron et al. (2008) stated that Carpenter (1997) claimed the L_{Aeq} prediction from the BS5228: Part 1: 1997 was inaccurate due to the fluctuation of noise in reality. Noise generated from the construction sites is not constant and fluctuates. The fluctuating of noise during the construction is due to the nature of activities, the type of equipments used, the nature of environment such as the terrain where the construction activity takes place, and the condition of the equipments (Gannoruwa and Ruwanpura, 2007; Gilchrist *et al*., 2002).

Therefore, to overcome these problems, Carpenter (1997) proposed the use of stochastic approach, also known as non-deterministic system in which the output of the prediction consists of random elements. The primary advantage of using the stochastic approach is the respective state variable may result in a cumulative behaviour suitable for predicting the environment condition changes (Cabecinha *et al*., 2003). Moreover, stochastic approach is considered as a powerful tool for assessing the environmental impacts of noise (Hamoda, 2008). Previously, noise prediction by using a stochastic approach has been introduced by Carpenter (1997). Then, Waddington and Lewis (2000) further developed the new model of noise prediction by using stochastic approach based on Monte Carlo method and continued by Haron and Olham (2004, 2005), Haron and Yahya (2009), Haron *et al.* (2011), and Idris and Haron (2011). The basic idea of noise prediction by using a stochastic approach is due to behaviour of noise in reality that fluctuates or changes randomly. The stochastic variables depend on the variability of noise source. Then, the model generates random numbers in order to sample the stochastic variables randomly. After that, the stochastic variables become the input to the deterministic equations and the noise level can be predicted. As a result, the cumulative distribution function (CDF) can be produced and from that, the noise equivalent noise level, L_{Aeq} and the time history of noise level arising from construction sites can be obtained. In addition, the methods also provide the statistical information.

1.3 Problem Statement

Recently, there are many researches and development of noise prediction using stochastic approach (Waddington and Lewis, 2000; Gilchrist *et al.*, 2003; Haron and Oldham, 2004; Gannoruwa and Ruwanpura, 2007; Haron and Yahya, 2009; Haron *et* *al.*, 2009 and Idris and Haron, 2012), and the overall results are in good agreement with the field measurement and standard method. Most of the developed models for noise prediction used Monte Carlo method and only considered random location and random acoustic power as stochastic variables in their prediction. However, the predictions of noise using stochastic approach require improvement to apply to a particular construction site. Current model of the predictions of noise using stochastic approach was not carried out in a detailed manner with absence of factors that may affect the noise, such as attenuation due to ground surface and atmospheric absorption. The types of ground surfaces at construction sites differ from each site, such as hard ground, mixed ground and porous ground. The behaviour and characteristics of the ground surface change over a wide area and this effect depends on the height of the source and receiver on the ground. Moreover, the noise levels at the receiver also vary depending on the atmospheric absorption, which increases linearly with distance. Therefore, the improvement of the method for noise prediction using Monte Carlo approach is required to apply to a particular construction site, considering the variability position and height of the sources, as well as receiver and variability of outdoor sound propagation, such as the attenuation of ground surface condition, atmospheric absorption and meteorological condition, that may affect noise level from the construction site. This information is needed to acquire more accurate result on noise prediction. In addition, the automated method for modelling of noise prediction needs to be developed.

1.4 Aim and Objectives

The aim of this research is to develop an automated computation that can predict the noise from the construction site which can be used at the planning stage by using stochastic approach. The following objectives are identified as the steps towards this goal:

a) To investigate the accuracy of noise prediction by using BS5228: Part 1: 2009 by comparing the predicted results with the measurement of real data from construction sites.

b) To improve the method of noise prediction using stochastic approach by considering ground surface condition and atmospheric absorption factors that contribute to noise level uncertainties.

c) To develop an automated model for noise prediction.

d) To verify the results obtained from automated prediction tool with the on-site measurement and those calculated using deterministic approach of BS5228: Part 1: 2009.

1.5 Research Scope

The scopes of the study are as follow:

i. This study focused on stages of earthwork activities at the construction site in Johor Bahru. The on-site noise measurements were conducted at two construction sites located at Pulai and Setia Tropika.

ii. The simulation of the noise emission focused more on L_{Aeq}.

iii. The development of stochastic modelling system in noise prediction was based on the Monte Carlo approach and was implemented in MATLAB 7.10.

iv. The interface of the stochastic modelling was designed in Graphical User Interface (GUI) and was limited to maximum of 10 machineries.

1.6 Significance of Research

Stochastic modelling is the most popular method in many areas in science and engineering such as for infrastructure deterioration prediction. Therefore, by using stochastic modelling in the prediction of noise, the result is more accurate and stable compared to deterministic approach. Modelling of noise prediction enables the determination of any indices required in evaluating the environmental quality and can facilitate the decision making process where noise is a potential problem. The modelling tool can also be used in determining the risk of quality of sound. In addition, the noise prediction modelling is developed using by Graphical User Interface (GUI) in MATLAB software, which is user-friendly.

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