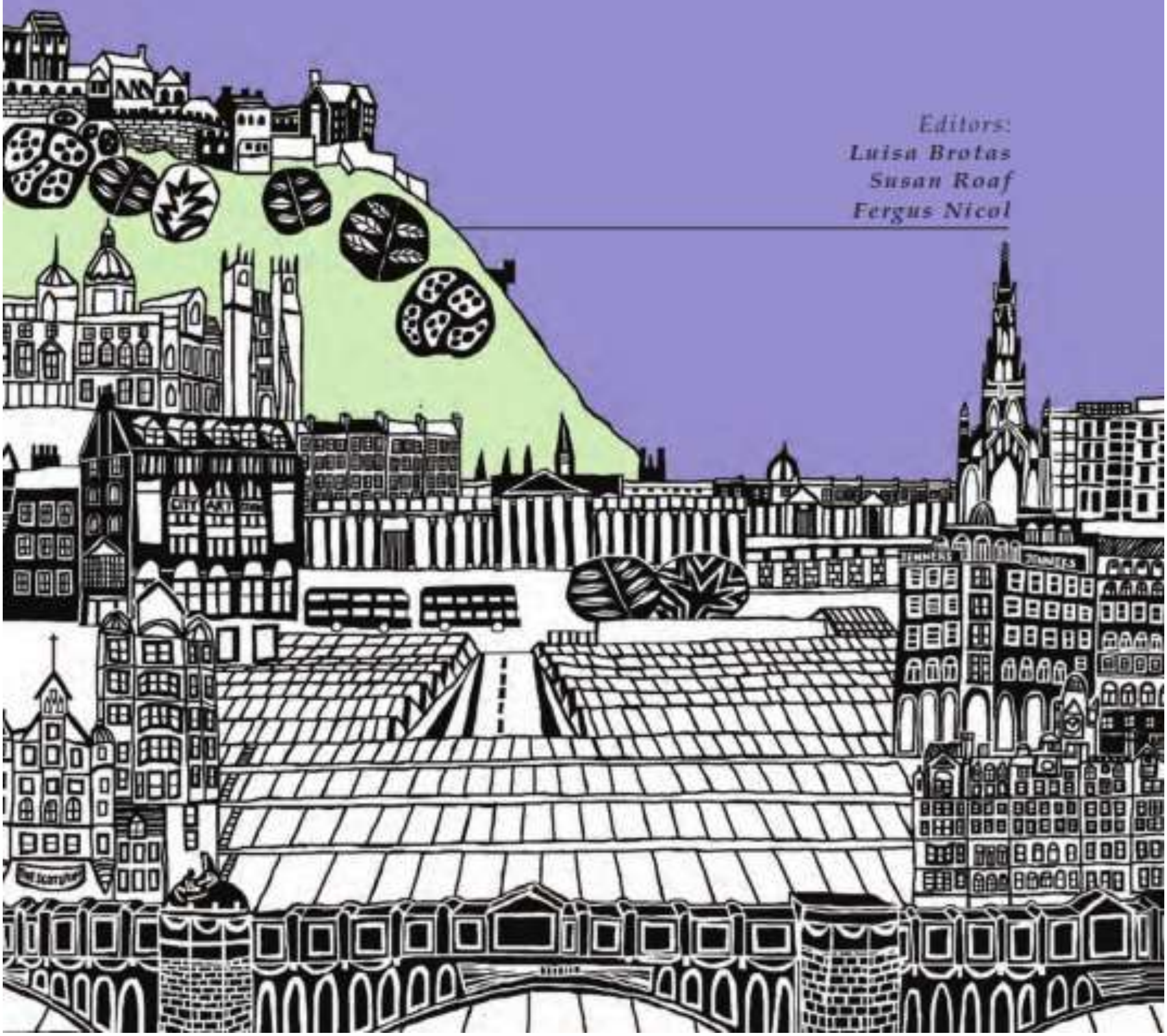
DESIGN TO THRIVE

Proceedings
Volume III

PLEA 2017 Conference



Editors:
Luisa Brotas
Susan Roaf
Fergus Nicol

Design to Thrive - PLEA 2017

Proceedings of 33rd PLEA International Conference
Design to Thrive
Edinburgh, 2th-5th July 2017
PLEA 2017 Conference www.plea2017.net

Published by NCEUB 2017
Network for Comfort and Energy Use in Buildings http://nceub.org.uk
to download go online to www.nceub.org.uk

All contributions to the 2017 PLEA Conference included herein were independently peer reviewed as a full paper, prior to publication.

ISBN 978-0-9928957-5-4

Table of Contents

Papers in the table of contents have links to the associated paper in the book.
To go back to the table of contents press the image logo on the top on the paper.

Open windows for natural ventilation and outdoor noise reduction in tropical climates

Christina Mediastika[1], Luciana Kristanto[1], Juliana Anggono[2], Fefen Suhedi[3], Hariyati Purwaningsih[4]

[1]Department of Architecture, Petra Christian University, Surabaya 60236, Indonesia, eviutami@petra.ac.id

[2]Department of Mechanical Engineering, Petra Christian University, Surabaya 60236, Indonesia

[3]Research and Development Centre for Housing and Settlement, Ministry of Public Works and Housing, Bandung 40622 Indonesia

[4]Department of Material Engineering, Institut Teknologi Sepuluh Nopember, Surabaya 60111 Indonesia

Abstract: 'Real' open windows for buildings in tropical climates were studied. It focused on the window degree of openings and window orientation toward the noise source. The window type to be tested was top-hung shutter type only, based on multitasking duty between permitting airflow and noise blockage. The top-hung open window with a uPVC frame was tested of 3 orientations, i.e. perpendicular, oblique 60°, and 90°. The degree of openings was tested on 0° (closed), 5°, and 10°. Laboratory tests according to ASTM E90-09 were conducted to determine transmission loss (TL) & ASTM E1332-90 was referred to calculate the outdoor-indoor transmission class (OITC). Later, finite element analysis using COMSOL 5.0 was conducted to study the sound contour developed around the models. The study revealed that window orientation has little effects of noise reduction. Here, a 'real' open window is still not capable of blocking noise into the living spaces. However, when the open window was closed, perpendicular orientation offered higher OITC compared to the oblique ones. Thus, a perpendicular orientation is more recommended to reduce noise.

Keywords: natural ventilation, tropical climate, open window, top-hung window, OITC

Introduction

Buildings in tropical climates encounter totally contradictory requirements between using lightweight materials and open envelopes for natural cooling and using weighty materials for environmental noise blockage. 'Real' open windows were studied here. The term real open window is used to separate it from a partially open double layered window suggested for ventilation and noise abatement (Ford and Kerry, 1973 and Burrati 2002 & 2006), but impractical for tropical climates. In a tropical warm-humid climate, a passive cooling by means of open windows shall have an open area of at least 5% of the ventilated floor area (SNI 03-6572-2001). As an example, a 15 sqm floor area will need 0.75 sqm of openings. With a partially open doubled layered window with say a maximum gap of 0.2 m, the room will need window as wide as 3.75 m, which is considered impractical for 15 sqm floor area only.

The existence of real open windows where the use of mechanical ventilation is mostly at night time due to energy saving issue and even for public buildings with the energy savings in mind is significant. A real open window that may conquer noise intrusion is a later issue. Openings placement on a wall will reduce the wall sound insulation property. As in general glass walls are thinner than masonry walls, the sound insulation property decreases accordingly (Quirt, 1981; Quirt 1982; Garg et al, 2011). Earlier studies have indicated that in warm temperature, laminated glass offered the best STC and TL contour compared to monolithic and tempered glass. But the OITC was low due to a coincidence dip developed at 125 Hz (Mediastika et al, 2015; Mediastika et al, 2016a). In overall, the use of glass in a temperature warmer than the ASTM E90-09 was suggested to be slightly thicker. In warm temperature, the STC and OITC of glass are 1 to 2 levels lower (Mediastika et al, 2015; Mediastika et al, 2016a).

Besides the specific glazing type of windows that will work for warm temperature, an earlier study has also recommended a particular framing material for conquering noise intrusion by an open window. When the open window was closed, a uPVC frame offered the best insulation. A laboratory test of timber, Aluminium, and uPVC proved that insignificant sound insulation was gained when the windows were opened (Mediastika et al, 2016b). In the study reported here, the orientations of glass windows to the noise source were tested in the laboratory of 1 to 1 scale, analysed, and verified using COMSOL 5.0 Multiphysics regarding the sound contour developed around the specimen.

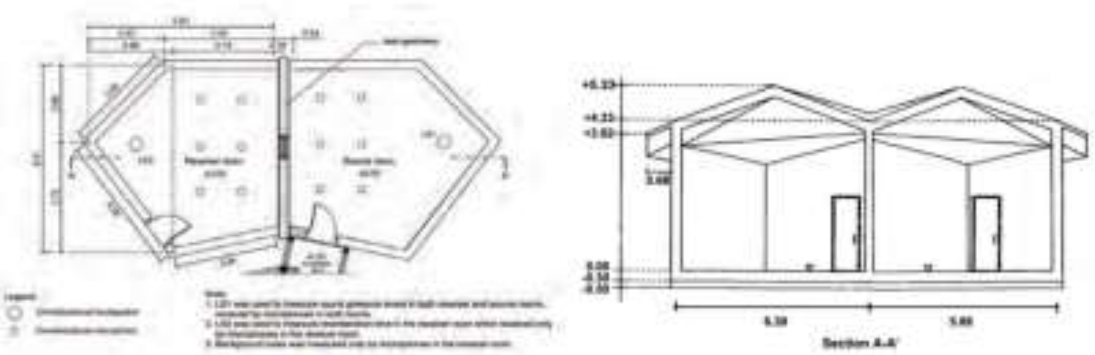
Methods

The study reported here is a series of empirical research, some have been reported and published, i.e. study on insulation properties of several glass types and study on the insulation properties of framing material for glass windows. The studies were conducted comprehensively using the following methods.

- Selection of glass types to be tested based on glass types commonly used for building facades in Indonesia (Anonymous, 2015). The tested specimens were monolithic, tempered and laminated. They were tested using ASTM E90-09 with a specific condition was applied based on Annex.3 on the use of the composite wall system (Figure 1). Equipment used for testing was Bruel & Kjaer 2- channel building acoustic system consisting of power amplifier type 2734 and 4292 omnidirectional loudspeakers as the sound source, 2 pieces of type 4189 omnidirectional microphones as the sound sensor, and 2-channel handheld analyzer type 2270 as the main instrument data processor. The microphones were calibrated using type 4231 prior to the testing stage. The room temperature was set at 27°C to 32°C as a replica of the average daily temperature of tropical climate (Feriadi & Wong, 2004; Hariyanto, 2005; Karyono, 2000). The first stage of glass testing showed that laminated glass types offered the best TL contour and STC, but not of the OITC due to a coincidence dip at 125 Hz.
- The next stage was to test frame materials suitable for openable windows and that are commonly used in Indonesia, which is timber, Aluminium, and uPVC. They were tested using ASTM E90-09 with a specific condition were applied based on Annex.3 with laboratory equipment as were used during the first testing stage. The second testing stage concluded that with rubber strips and sealant, a uPVC frame offered the best insulation for both fix and open windows when the open window was closed.
- The third testing stage reported here was to study the orientations of glass window toward the noise. It is perpendicular, oblique 60° and oblique 90° (Figure 2). A particular glass window type; top-hung; was selected due to shutter position that may

block noise pathways. Glass type, glass dimension, and frame material were the fix variables, which is monolithic glass, 10 mm thickness, 800 mm x 1200 mm, and uPVC frame (Figure 2). With the early testing stages have indicated the best insulation offered by a glass type and a frame material, glass type and frame material used at this stage were based only on resources limitation and the ease of installation. The testing method and equipment employed at this stage was similar to those of the earlier stages. The temperature and relative humidity (RH) during the testing period were 25°-26°C and 80% - 90%.

- In this study, the orientations of the open windows were assigned as the variable to be tested, but the window style was determined as a fixed variable. It was a top-hung open window style. The top hung style was selected based on the capability to permit ventilation and the possibility of noise blockage by the shutter position (De Salis, et al, 2002, Figure 2). Gao and Lee (2010) determined that the top-hung window type was the worst in natural ventilation compared to end-slider and side-hung. But these 3 types were chosen by Gao and Lee as the possible types for natural ventilation only. The lowest ventilation rate by the top- hung window was caused by the shutter position that blocked the airflow. However, still, a top-hung window was capable of supplying natural ventilation (Coley, 2008) when be compared to the 'non-real' open window (Ford and Kerry, 1973 and Burrati 2002 & 2006). Another window type with similar shutter position to top-hung, such as bottom-hung was not tested due to the limited resources. Besides, the bottom-hung window is rarely used in Indonesia caused by the less accessible handle and latch.
- The top-hung window was tested at 3 degrees of openings, i.e. 0° (closed), 5°, and 10° (Figure 3 and 4). The closed condition was tested to study whether the gap between frame and the shutter has an effect on noise intrusion due to the window position. The 10° was selected as the maximum degree of opening for safety reason and ease of people movement along the corridor or space by the window.
- The OITCs were calculated from the TL of 1/3 octave band frequency according to ASTM E1332-90.
- The test specimen was then modelled in a finite element analysis using COMSOL 5.0 Multiphysics to study the sound contour around the specimen to confirm the finding of the laboratory test.



(a) (b)

Figure 1. Plan of the testing rooms and the equipment layout (a) and section (b).

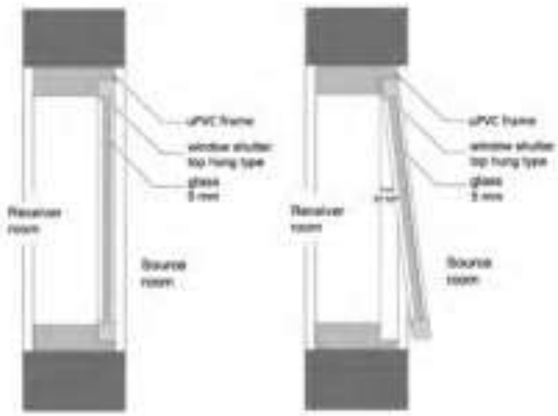
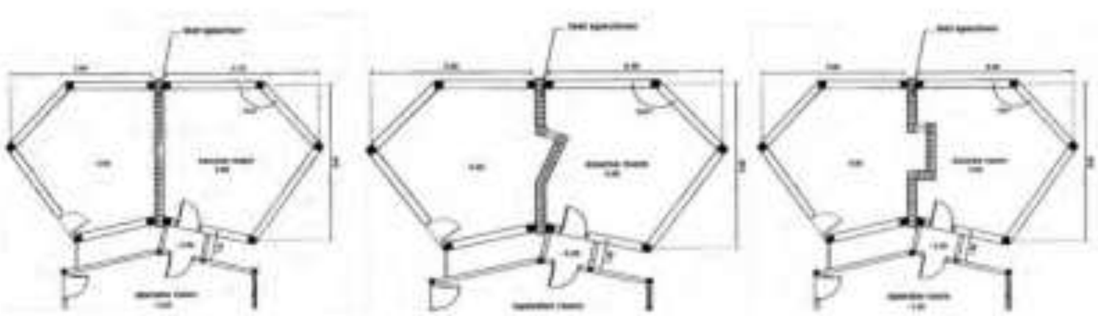
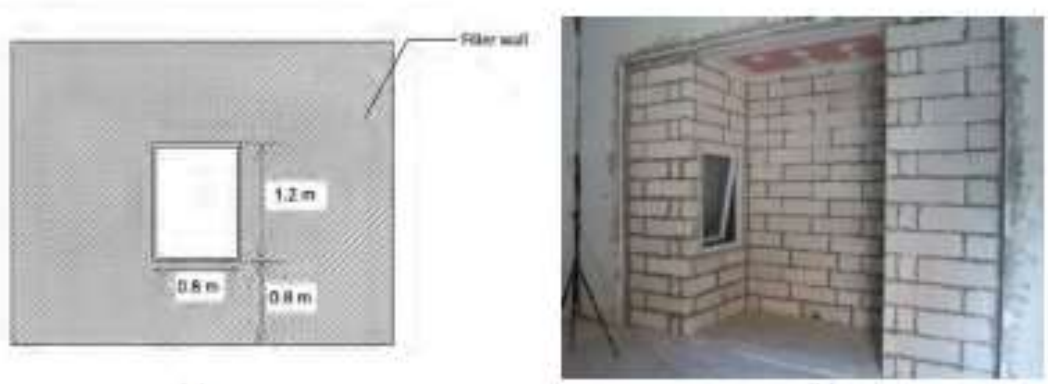


Figure 2. Section showing the degree of openings of the window shutter; 0° (a) and 5° and 10° (b).



(a) (b) (c)

Figure 3. Plan of the window specimen's orientation: perpendicular (a), oblique 60° (b), and oblique 90° (c).



(a) (b)

Figure 4. Schematic front view of perpendicular composite wall (a) and view of the oblique 90° composite wall specimen from the receiver room during construction (b).

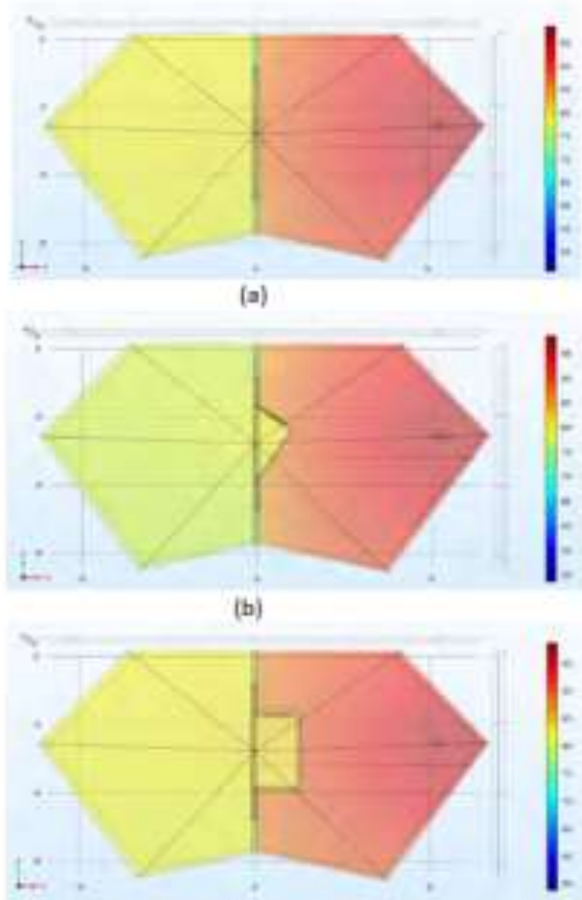
Findings and Discussion

A series of laboratory test has been conducted to see the effect of a top-hung open window in blocking noise. The result of the laboratory test is compiled in Table 1. When the open windows were closed (open 0°), the OITC of perpendicular orientation were higher than the oblique ones. But when they were opened, the OITC values were similar regardless orientations, either perpendicular or oblique and regardless degrees of obliqueness. These findings strengthen earlier studies that larger degree of openings permits noise intrusion easier (De Salis, et al, 2002). Both the oblique that seemed to have a larger open area and the perpendicular that seemed to have a smaller open area due to the shutter positioned parallel to noise performed similar OITC.

Later, the laboratory findings, which showed that insulation values of either oblique 60 (or 90 (were similar were confirmed using finite element simulation to see the sound contours developed around the openings. Figure 5 shows that both orientation results in similar sound contour, sound dispersion, and sound levels. It means that either 60° or 90° obliques did not offer different insulation values to noise. It is more interesting to study the sound transmission loss (TL) contour of the specimen shown in Figure 6. Here, all closed open windows drawn similar contours except the oblique, which indicated a coincidence dip at 80 Hz. It was predicted not due to the gap position between the frame and the shutter, but due more to the presence of an angle of the oblique wall. However, the finite element analysis showed that the sound dispersion developed around the openings is similar, means that the wall's angle did not affect the sound contours. One thing should be remembered, simulation by using finite element does not consider the sound frequency. It is only the sound intensity that is taken into account. Thus, the condition of coincidence dip was not represented in the simulation. A further test conducted in a laboratory with larger dimension to accommodate low sound frequencies pathways, is significant to confirm this finding.

Table1. Transmission loss and STC/OITC of perpendicular, oblique 60°, and oblique 90°.

1/3 Octave band frequency (Hz)	Perpendicular			Oblique 60°			Oblique 90°		
	Open 10°	Open 5°	Open 0° (closed)	Open 10°	Open 5°	Open 0° (closed)	Open 10°	Open 5°	Open 0° (closed)
80	18,0	19,0	31,0	18,0	19,0	14,0	18,0	19,0	14,0
100	16,0	18,0	29,0	16,0	18,0	24,0	16,0	18,0	24,0
125	9,0	9,0	21,0	5,0	6,0	17,0	5,0	6,0	17,0
160	4,0	6,0	21,0	7,0	9,0	20,0	7,0	9,0	20,0
200	4,0	7,0	20,0	4,0	5,0	18,0	4,0	5,0	18,0
250	5,0	8,0	21,0	6,0	8,0	20,0	6,0	8,0	20,0
315	6,0	9,0	22,0	7,0	8,0	21,0	7,0	8,0	21,0
400	3,0	7,0	22,0	4,0	7,0	22,0	4,0	7,0	22,0
500	3,0	6,0	23,0	3,0	7,0	23,0	3,0	7,0	23,0
630	4,0	6,0	27,0	4,0	6,0	24,0	4,0	6,0	24,0
800	4,0	5,0	29,0	5,0	6,0	25,0	5,0	6,0	25,0
1000	4,0	5,0	31,0	5,0	6,0	27,0	5,0	6,0	27,0
1250	4,0	6,0	34,0	5,0	6,0	30,0	5,0	6,0	30,0
1600	4,0	6,0	35,0	5,0	6,0	32,0	5,0	6,0	32,0
2000	5,0	6,0	33,0	5,0	7,0	33,0	5,0	7,0	33,0
2500	6,0	8,0	31,0	7,0	8,0	30,0	7,0	8,0	30,0
3150	7,0	10,0	31,0	7,0	11,0	31,0	7,0	11,0	31,0
4000	6,0	11,0	33,0	7,0	11,0	33,0	7,0	11,0	33,0
OITC	**5**	**7**	**25**	**5**	**7**	**23**	**5**	**7**	**23**

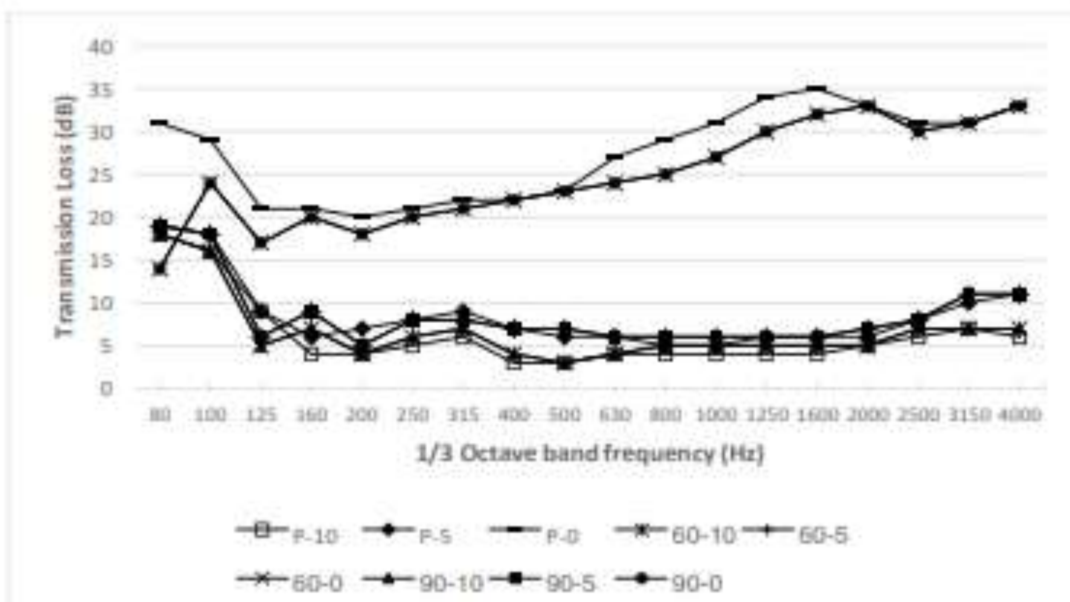


(a)

(b)

(c)

Figure 5. Sound distribution and contour developed around the perpendicular open window (a), oblique 60°, (b) and oblique 90° (c).



Legend: P is perpendicular orientation, 60 is oblique 60°, 90 is oblique 90°, 10, 5 and 0 is the degree of openings

Figure. 6. TL contour of the tested specimen.

Conclusion and recommendation

The laboratory test and the computational simulation were in good agreement. The laboratory test showed a 'real' open window of a top-hung style offered OITC as low as 5, regardless window orientations. It was supported by the COMSOL simulation that showed TL contours developed around the model were of high noise levels. The offered OITC value is considered too small to reduce environmental noise in the residential area, which might reach up to 75 dB (Iswar, 2005). But when the open window was closed, perpendicular orientation resulted in higher OITC compared to the oblique ones. Five degrees of openings resulted in OITC of roughly 2 points higher than the 10°. For natural ventilation purposes in tropical climates, 10° of openings may be preferable. But the users should be aware of the low OITC offered by 10° of openings. In overall, a 'real' open window positioned perpendicular to noise source is suggested to conquer noise whenever it is open or closed. A 'real' open window is still incapable of providing significant noise reduction whatsoever.

Acknowledgment

This study was fully funded by Ministry of Research, Technology and the Higher Education Republic of Indonesia under the scheme of Penelitian Kompetensi under the project "Acoustical Characteristic of Architectural Glass in Warm Humid Climate" with contract number 023.04.1.673453/2015 and 002/SP2H/P/K7/KM/2016 (made through Kopertis Wilayah VII Indonesia).

References

ASTM E90-09. Standard test method for laboratory measurement of airborne sound transmission loss of building partitions and elements, American Society for Testing and Materials, West Conshohocken, PA, 19428-2959 USA, 2009.

ASTM E1332-90, Standard Classification for Determination of Outdoor-Indoor Transmission Class, American Society for Testing and Materials, West Conshohocken, PA, 19428-2959 USA, 1998, superseded by ASTM E1332-10a, Standard Classification for Rating Outdoor Indoor Sound Attenuation, American Society for Testing and Materials, West Conshohocken, PA, 19428-2959 USA, 2010

Anonymous, 2015. *Tiga jenis kaca yang sering digunakan pada bangunan*, available on infoklasika.print.kompas.com/tiga-jenis-kaca-yang-sering-digunakan-pada-bangunan/ accessed on March 25th, 2015

Anonymous, (2001). Standar Nasional Indonesia SNI 03-6572-2001, National Standardisation Agency of Indonesia

Buratti, C. (2002). Indoor noise reduction index with open window, Applied Acoustics 63 383-401.

Buratti, C. (2006). Indoor noise reduction index with an open window (part II), Applied Acoustics 6: 431-451.

Coley, David A. (2008). Representing top-hung windows in thermal models, International Journal of Ventilation, 7:2, 151-158

De Salis, M.H.F, Oldham, D.J, Sharples, S. (2002). Noise control strategies for naturally ventilated buildings, Building and Environment 37: 471–484

Feriadi H. Wong, N.H. (2004). Thermal comfort for naturally ventilated houses in Indonesia. Energy and Building, 36: 614-626.

Ford, R.D., Kerry, G. (1973). The sound insulation of partially open double glazing, Applied Acoustics 6: 57-72

Gao, C. F., Lee, W. L. (2010). Influence of window types on natural ventilation of residential buildings in Hong Kong, Proceeding of International High Performance Buildings Conference, paper 16, Purdue e-Pubs, Purdue University, USA.

Garg N., Sharma, O., Maji S. (2011). Experimental investigations on sound insulation through single, double & triple window glazing for traffic noise abatement. J Sci Ind Res 70: 471-478

Hariyanto, A.D. (2005). Thermal comfort study of an air-conditioned design studio in tropical Surabaya. Dimensi Journal of Architecture and Built Environment, 33(1): 76-86

Iswar (2005). *Tingkat kebisingan dan nilai kebisingan di perumahan, studi kasus perumahan dosen UGM, Sekip Yogyakarta*, unpublished Master dissertation, UGM, Yogyakarta

Karyono T.H. (2000). Report on Thermal Comfort and Building Energy Studies in Jakarta, Indonesia. Building and Environment, 35: 77-90.

Mediastika, C.E., Kristanto, L., Anggono, J., Suhedi, F., Purwaningsih, H. (2015). Sound transmission class (STC) of fixed window glazing in warm humid environment, Proc 7th International Conference on Environmental Science and Development (ICESD), Athens

Mediastika, C.E., Kristanto, L., Anggono, J., Suhedi, F., Purwaningsih, H. (2016). Building glass OITC in warm temperature, Procedia Engineering 145: 630-637.

Quirt, JD. (1982). Sound transmission through windows I single and double glazing. J. Acoust. Soc. Am 72: 34-844

Quirt, JD. (1981). Measurement of the sound transmission loss of windows. Building Research Note 72:1-7

ORGANISERS

PLEA
Sustainable Architecture and Urban Design

THE UNIVERSITY *of* EDINBURGH
Edinburgh College of Art

HERIOT WATT UNIVERSITY

University of Strathclyde Glasgow

GCU Glasgow Caledonian University

MACKINTOSH ENVIRONMENTAL ARCHITECTURE RESEARCH UNIT
THE GLASGOW SCHOOL OF ART

RGU ROBERT GORDON UNIVERSITY ABERDEEN

Edinburgh Napier UNIVERSITY

OUR PARTNERS

nceub

RIAS

CIBSE Scotland

RESILIENT DESIGN INSTITUTE

HISTORIC ENVIRONMENT SCOTLAND | ÀRAINNEACHD EACHDRAIDHEIL ALBA

OUR SPONSORS

AES Solar EST. 1979

VELUX®

HISTORIC ENVIRONMENT SCOTLAND | ÀRAINNEACHD EACHDRAIDHEIL ALBA

BENNETTS ASSOCIATES