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Building Materials Composition Influence to Sound Transmission Loss (STL) Reduction

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Abstract. The development of the airport always causes the noise impact to the surrounding environment.[1] Housing close to the airport will be annoyed by the aircraft noise, especially if the building is not added by absorber building materials. Housing lay out towards the runways as noise sources is also an aspect that should be considered. This research resulted building models equipped by simple material compositions that had capability in reducing the airport noise optimally. The decrease of the noise level found out from the research is caused by the value of Sound Transmission Loss (STL) of the building materials composition. The models of housing are laid out with a number of specific orientation angles towards the runway and resulted values of the highest noise level reduction.

Introduction

The issue of airport noise becomes a great and important problem, especially in term on the impact of airport noise to the housing in the vicinity. Housing lay out that is not designed properly and building materials composition which is not equipped with silencers to be the cause of housing failure in anticipation of the airport noise.[2, 3] To be able to test one sample cluster housing near the airport, the researchers then built replicas of the housing consist of building material composition equipped with silencer. Further replicas of building are referred to as building models. Building models are not only equipped with any silencer elements, but also can be rotated as those have wheels and rotary axes. With this rotation, it can be determined that the more effective orientation angle towards the runway the higher value of sound reduction.

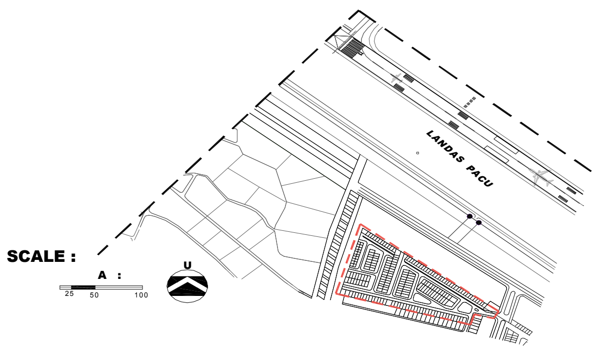


Figure 1: Site plan of Avonia Cluster

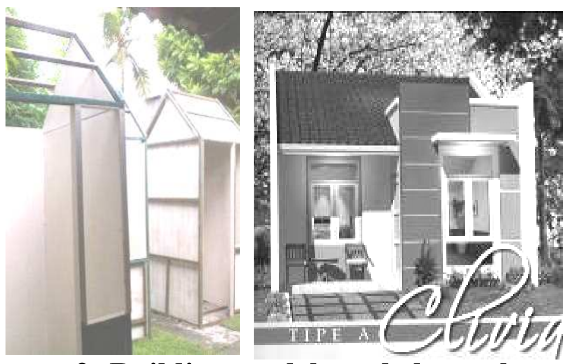


Figure 2: Building models and cluster house

Building Models

Building models were made depend on the basis of the cluster housing condition near the airport. Building material composition of the models was made to have the same value of Sound Transmission Loss (STL) to those of the cluster housings.

The Comparison of Housing Cluster and Building Modeling. The cluster of Avonia is part of the Graha Padma housings in Semarang. The housing is located near the airport and disturbed by noise generated from aircraft when it is landing and taking off. The noisest point of the cluster is only 310 meters from the airport runway (see figure 1). The building models were made in two types, the first was a model that was not covered by styrofoam, and the second was a model layered with 12 mm Styrofoam sheets [4] (see figure 2). The models that was not layered with 12 mm Styrofoam sheet, had a value of 19.98 dB in Sound Transmission Loss (STL). The value was still very low, whereas the STL value in the housing cluster was 28.95 dB. Later, models of the building were layered with 12 mm styrofoam to get a higher STL value. Finally, the STL value of models which were layered with Styrofoam sheet was 28.95 dB. The STL value was equal to those values of housings in the cluster. Here are tables of STL values of building models.

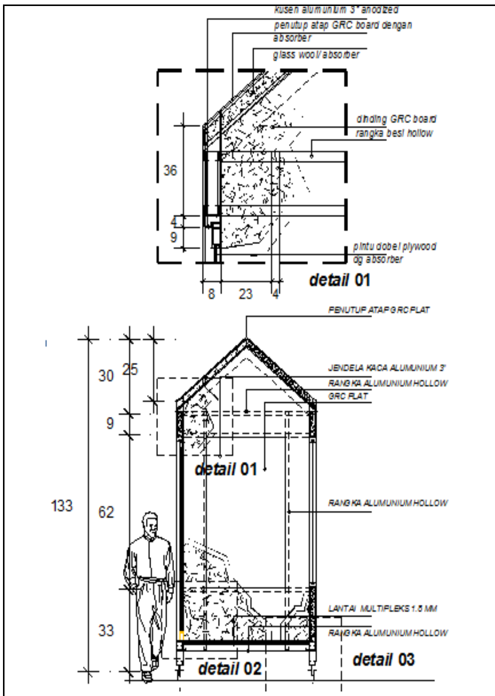


Figure3:Building Model before layered by 18 mm styrofoam

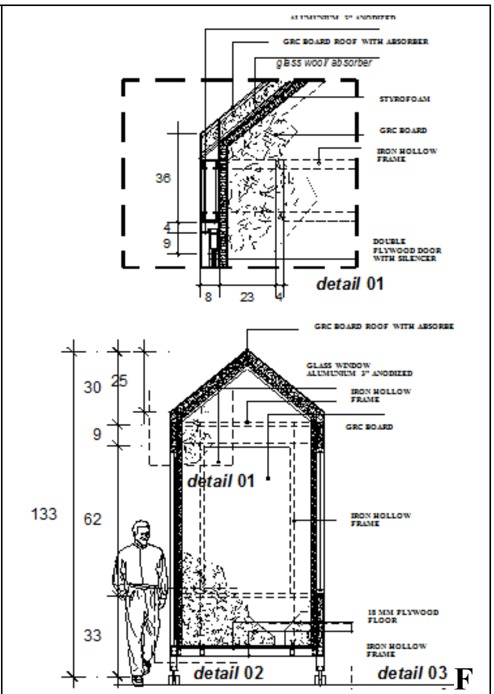
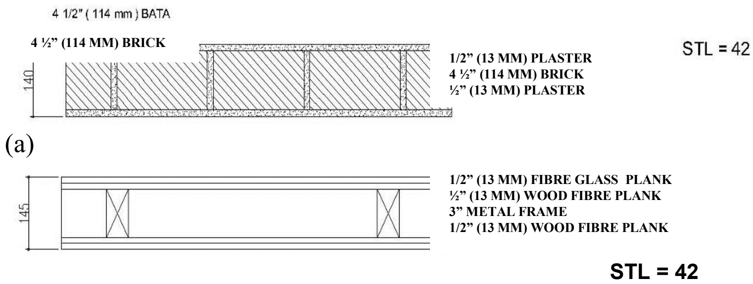


Figure 4: Building Model after layered by 18 mm styrofoam



(b)

Figure 5: (a) Building material composition in the real cluster house ; (b) Building material composition in building modelling

Table 2: Sound Transmission Loss (STL) of Un-styrofoamed Model

PERIODS	HOUSING MODEL		DISTANCE (M)	STL (dB)
	INSIDE(dB)	OUTSIDE(dB)		
I	54.38	73.88	1	19.49
II	53.79	74.25	1	20.47
			STL MEAN	19.98

Since the STL value is still too low, then the model and then coupled with absorber layer. Absorber used to enhance the value of STL is styrofoam.

Table 3: Sound Transmission Loss (STL) of Styrofoamed Model

PERIODS	HOUSING MODEL		DISTANCE (M)	STL (dB)
	INSIDE (dB)	OUTSIDE (dB)		
I	52,21	81,45	1	29,24
II	51,66	80,56	1	28,90
III	51,00	80,54	1	29,54
IV	53,72	81,25	1	27,53
V	52,45	81,98	1	29,53
			Σ STL	144,74
			STL MEAN	28,95

Rotation of Models. In some journals that I wrote that the building models are not assumed to be a single model. In some journals, they are perceived as building models represented a replica of a block of houses in a cluster. Building models are assumed to be a group of housings. However, in this study the model building is perceived as a single model. The main objectives of this research are: [5, 6]

Proving that the differences in composition of the material will cause a decrease in the value of Sound Transmission Loss (STL).

The rotation of models in their axes describing various angles of orientation towards the airport runway will cause differences in the value of the sound level received by the inhabitant.

Determining the most effective orientation angle (α) in reducing noise.

Research Methods

Researchers used two methods to determine the level of sound received by the inhabitant in the building models. The two methods are:

Determination of sound level by a Sound Level Meter (SLM).

Determination of sound level by using formula of Inverse square law method.

The formula used to determine the sound level is obtained by using the formula of equivalent sound level as belows: [7, 8]

$$L_{eq} = 10\log_{10}\frac{1}{N}\sum n_i 10^{0,1L_i} \tag{1}$$

n_i : number of incidents by level L_i

N : Number of incidents

T_i : time duration of level L_i

T : total time duration

To calculate the noise reduction due to the distance in open space, it can use the units both in *deci Bell* and in *Watt/m²* as shown in equations (1) [7] and (2) [8] below:

$$L_2 = L_1 - 10\log\left(\frac{r_2}{r_1}\right) \tag{2}$$

L_1: Noise Level by the distance r_1 in *deci Bell*

r_1 : Distance between source L_1 and receiver (m)

L_2: Noise Level by the distance r_2 in *deci Bell*

r_2 : Distance between source L_2 and receiver (m)

$$L_1 = 10\log\left(\frac{I_1}{I_0}\right) \tag{3}$$

L_1: Tingkat Bunyi pada jarak r_1 dalam deci Bell

I_1 : Intensitas kebisingan pada jarak r_1 dari sumber (Watt/m^2)

I_0: Intensitas Bunyi referensi = 10^{-12} Watt/m^2

Researchers used a span of 2 minutes per 3 seconds method in measuring the sound level equivalent. This method was choosen because the range of the most important aircraft noise emmited in only two minutes either at the time when the plane landed or the plane took off. Measurement range of two minutes per three seconds has turnover periods of sounds that is more accurate than the measurement range of two minutes per five seconds.

Research Analyses

In pursuit of the second aim of the rating point of orientation, the researchers used a method of determining the relative value (R_v). The formula is obtained by comparing the relative value of the rotated model to the sound level value of the control model (unrotated-model).
From this formula, by rotation of models in various rotation angles, it is found the various value of R_v (Relative value). The rating of relative values were analyzed by using statistical analysis of Comparative-Compare Means. The comparative method is a practical method among the other methods, because it is flexible in the amount of data as well as those simplicity of the experimental treatment.[9] Meanwhile, according to S. Santoso, SPSS 18 assisted easily in solving the rating of orientation angles by incorporating the data relative to the value in the data sheet, and analyzed after labeling process. [10, 11]

Sound level measurements performed well in the field when the aircraft landing and take-off. In each of the conditions to judge the models with varying orientation angles, ranging from: 0°, 30°, 45°, 60°, 90°, 120°, 135°, 150°, 180°, 210°, 225°, 240°, 270°, 300°, and 330°. In each orientation angle, the sound level of rotated model is compared with that of the unrotated model (control model). And the results are as follows:

TABLE 1 SUMMARY OF R_V MEANS INSIDE THE BUILDING IN THE TAKE-OFF PERIODS

ORIENTATION ANGLES	MEANS OF R_V	NOISE LEVEL CHANGE IN DECI BELL (dB)	$\overline{L} \pm S.deviation$ (dB)
0°-45°	1,195-	-22,00 to +23,00	3,72 ± 8,58
90°	0,980	-18,40 to +18,90	-1,39 ± 8,24
180°	0,866	-8.90 to + 3,20	-2,12 ± 3,16
60°-180°	0,866-	-24,20 to +19,00	-1,61 ± 6,98
210°-300°	0,997-	-23,90 to +24,10	0,35 ± 6,28
315°-330°	0,978-	-18,00 to +23,20	-0,77 ± 6,14

Note: (+) increasement of noise level ; (-) reduction of noise level

The curve indicated by a sound level orientation angle 210°, 225°, 240° and 270° are almost the same. The orientation angles that have range of 210°-300°, are the zones which their position are perpendicular to the plane when they are climbing up and reaches the sound peak, so these angles tend to raise the noise level in about 0,35 ± 6,26 dB. Orientations of 300°, 315° and 330° have a sound level curves are almost the same, the difference lies in the type of the sound source and the direction of the wind. The R_v value means are about 0,978-1,193. Orientation angles of 315° and 330° lies in the shadow area of to the planethe sound due to the height of the aircraft during takeoff, with a value of $Rv<1$, so that the orientation angles reduce the sound level of 0,77 ± 6,13 dB.

TABLE 2 SUMMARY OF R_V MEANS INSIDE THE BUILDING IN THE LANDING PERIODS

ORIENTATION ANGLES	MEANS OF R_V	NOISE LEVEL CHANGE IN DECI BELL (dB)	$\overline{L} \pm S.deviation$ (dB)
30°-120°	1,018-1,076	-24,20 to +19,00	0,27 ± 6,05
180°	0,738	-22,60 to +10,20	-2,11 ± 7,20
135°-240°	0,738-0,932	-26,80 to +21,50	-3,29 ± 6,98
210°	1,074	-13,40 to +8,50	0,76 ± 4,34
270°-330°	1,187-1,370	-25,40 to +32,40	2,22 ± 7,53

Note: (+) increasement of noise level ; (-) reduction of noise level

Orientation angles of 135°-240° are the sound shadow areas, with an average value of R_v ranged from 0.7377 to 0.9316. These orientation angles are able to reduce the sound level of about 3,29 ± 6,98 dB. The orientation angle of 180° has an average of 0.7377. This angle can reduce sound levels by 2,11 ± 7,20 dB. The angle orientation of 210° is susceptible to environmental reflections, the value of R_v = 1.074, so as to increase the sound level by an average of 0,176 ± 4,34 dB. The orientation of 330° have an average value of R_v highest at 1.370, because this orientation right facing position of the aircraft while the peak sound occurs. Wind direction opposite to the rate of the aircraft, resulting in the span of a brief peak sound level, which is 3-15 seconds after the plane landed. The orientation angle of 270°-330° are positioned directly facing the direction it comes time to land the aircraft. While mapping a sound level of analysis will be obtained as follows:

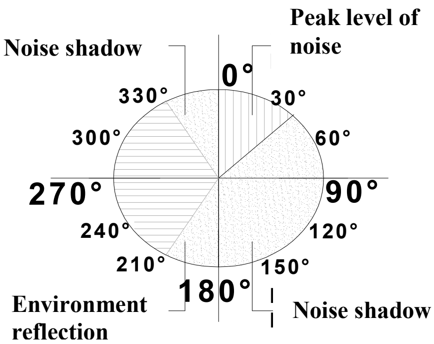


Figure 07: Noise mapping while take-off

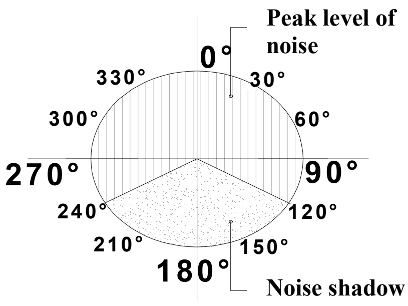


Figure 08: Noise mapping while landing

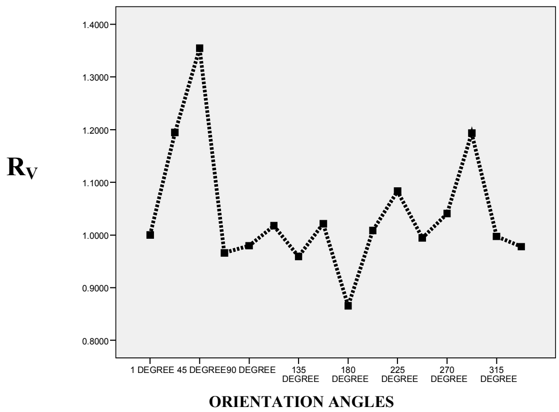


Figure 09: Rating Curve of Orientation Angles while take-off

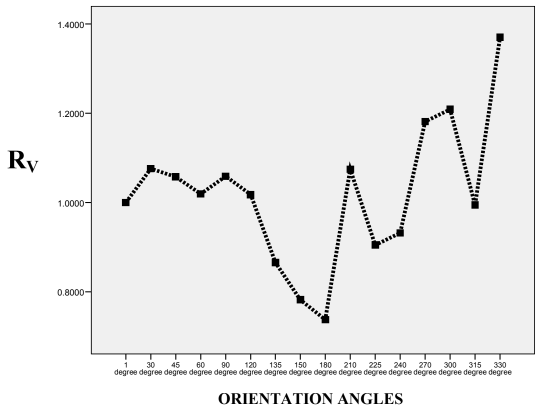


Figure 10: Rating Curve of Orientation Angles while landing

Summary

The building models are made with material composition with an equal value to the STL in the housing cluster. This modeling study proves that the reduction abilities of the model are varies depending on the orientation angle of the sound source in this case is the source of airport noise. Based on those facts, so this study concluded several matters as follows:

The difference in the composition of the building material will affect the value of Sound Transmission Loss.

The orientation of building model affects the sound level received by inhabitant inside the building.

The orientation angle of 180° is the most effctive angle in reducing the airport noise.

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