

## APPLICATION OF ACOUSTIC MATERIAL FOR FACADE TO REDUCE NOISE IMPACT IN BUILDING LOCATED NEAR FROM RAIL

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### ABSTRACT

*Facade is a main component to reduce noise impact from the outdoor area. A room is considered as a cozy place, if the condition is set with Noise Criteria (NC) of 30-35 dB (A). The standards of room comfort should be applied in each area, one of them is Hotel Sahid Surabaya building located close to the railway. Acoustic insulation is certainly necessary and applied in some elements of the facade building. A way to improve the comfort in the building is with selection of materials that will be applied to the interior wall. In addition there is reference such as the use of diffuser on the exterior wall. This research is about the increasing of acoustic insulation on the hotel room facade with case study of Sahid Hotel Surabaya by measuring level of acoustic insulation on the inner wall and outer wall in one of the hotel room. The research study is focused on the noise impacts caused by airborne sound.*

*This research use quasi experiment. The research objectives of this paper are to inform the wall insulation material in buildings and as a reference of the use exterior wall diffuser which are suitable for outdoor area. According to the earlier research, the use of a diffuser on the exterior facade is able to reduce noise until 30-35%. As for the results of an alternative design, the use of insulation material in the form of fibers with fiber type-800 on the inner wall has produced good insulation levels. This study is expected as a reference for designing especially buildings located close to the rail to support the acoustic comfort.*

**Keywords:** *airborne sound, diffuser, facade, insulation, noise criteria*

## ABSTRAK

*Fasad merupakan komponen utama untuk mereduksi bising dari lingkungan luar. Suatu ruangan yang digunakan untuk beristirahat dikatakan nyaman apabila berada pada kondisi dengan nilai Noise Criteria (NC) 30-35 dB. Standar kenyamanan tersebut sebaiknya dapat diterapkan dalam berbagai kondisi lingkungan, salah satunya adalah bangunan Hotel Sahid Surabaya yang berlokasi dekat dengan rel Kereta Api. Penelitian ini bertujuan untuk meningkatkan kenyamanan akustika bangunan dengan penggunaan material insulasi pada interior dan diffuser. Insulasi Akustik yang dapat diaplikasikan pada elemen arsitektural, seperti pemasangan material insulasi pada dinding interior, sedangkan diffuser merupakan material yang diletakkan pada bagian eksterior bangunan. Penelitian ini juga hanya fokus terhadap kebisingan yang disebabkan oleh perantara udara (Airborne Sound). Penelitian ini menggunakan metode eksperimen dan analisa. Tujuan penelitian ini untuk menginformasikan material insulasi dinding dalam bangunan serta rujukan penggunaan diffuser yang sesuai digunakan untuk kondisi eksterior bangunan. Hasil penelitian menunjukkan bahwa penggunaan diffuser dapat mengurangi kebisingan lingkungan antara 30-35 %. Sedangkan penambahan material insulasi fiber tipe fiber 800 pada bagian dalam merupakan modifikasi terbaik dari beberapa modifikasi yang diterapkan. Penelitian ini merupakan penelitian dapat menjadi rujukan saat mendesain, khususnya bangunan yang berlokasi di dekat rel kereta api untuk menunjang kenyamanan akustik.*

**Kata kunci:** *airborne sound, diffuser, fasad, insulasi, kriteria kebisingan*

## INTRODUCTION

The developments of hotel which are close to railroad needs good acoustics optimization in their constructions. This is caused by noise levels that arise, thus causing the sound leakage into the building. This step was taken as an initial solution as a result of additional quota policy by KAI (Kereta Api Indonesia / Indonesian Train) due to the departure of train from the railway users increased 37.22% in the last year (Tempo, June 2014). The addition of railroad activity will also add a burden of noise along the rail, it increases sound leakage. This occurs if the applied partitions do not meet the minimum standards that are not able to withstand and absorb the noise from outside. Therefore, a good acoustic insulation in the building is necessary, for example the application of acoustic material for the hotel walls as well as the shading processing or diffuser on the building exterior facade.

The noise level at surrounding areas of Sahid Hotel has certainly exceeded the threshold of comfort viewed by previous measurements of the noise environment around the track. From these conditions, Sahid Hotel needs acoustic insulation applied to the building in order to achieve the standards comfort. Noise source that affects the surrounding areas of Sahid Hotel is moving noise pollution (Mediastika, 2005). The sources of the noise pollution are caused by the train and highway noise. However, this study will discuss and deepen the noise factor that comes from the

trains. Reason for this selection because the discussion regarding the noise in the hospitality building located close to the railroad tracks are still rarely discussed.

To support and provide comfort for customers from noise pollution, each hotel room has a standard of comfort that does not exceed more than 35 dB (Doelle, 1985). In this case study, the hotel located close to rail where the noise level is quite high. It is needed proper wall insulation materials to reduce noise pollution. Moreover, it can also use shading and diffuser which may be a reference as the exterior building facade. Because this study has been conducted by Picaut et al. (2010) that occurred a significant reduction in noise by using of diffuser on the facade.

## **THEORY / RESEARCH METHODS**

### **Hotel Building**

The definition the word of hotel is derived from the Greek, *Hosteis* meaning provide shelter for visitors by providing a certain fee to the owner. The definition of hotel according to Stedmon and Kasavana (2005), as a foundation of AHMA (The America Hotel and Motel Association), "Ahotel may be defined as an establishment whose primary business is providing lodging facilities for the general public and which furnishes one or more of the following services: food and beverage service, and other services.

Hotel is a building of hospitality type, which means that the building provides services and the services are around the globe, with no exception in Indonesia. Today, the hotel developments are very visible, especially in big cities in Indonesia. One of is Surabaya as the second largest city after the capital city of Jakarta. From type, hotel is distinguished on several types (Neufert, 1980): such as City Center, Motor Hotels, Airport Hotels and Resort Hotels. Sahid Hotel is in the category of City Center. The explanation of this type is as follows:

**City Center** - This type is more an impression of a luxury. It usually located in downtown. The hotel is commonly used for business purposes and the building construction is a high rise building.

### **Noise**

The noise itself is a unwanted sound, including in this case the interfere sound. Basically the interference sound at a particular stage can be tolerated by the physical, but there is no doubt that the sound effects on the nerves. (Satwiko, 2004).

To overcome the noise, first thing to do is find out the source of the noise and determine the right way to reduce the noise. Noise sources may come from the interior or exterior. Interior noise is usually caused by humans, household appliances, electronic devices, etc. For exterior noise may come from vehicles activity, such as highway traffi, the noise of passing train and the activity from airplanes. In addition, outdoor noise can also be exemplified by the noise caused by construction equipments. The medium of noise propagation in buildings can be divided into two types,

air (airborne sound) and solid (structureborne sound) (Mediastika, 2009). But in this research is more focused on the propagation through the airborne sound.

### Airborne

The propagation of sound wave through airborne is vibrations that arise from the sound source to the air molecules which located around the sound source.

As mentioned above that noise may occur in the air, because it is basically a freeway so the noise in the air can easily spread around. (Smith, Peters and Owen, 1996). Airborne sound itself is the propagation of sound waves that occurred through air. Intermediary medium.

### Noise Level

The tool used in measuring the noise as described previously is Sound Level Meter (SLM). Basically SLM facilitates to measure because it can convert from the actual noise level (La) to the equivalent noise level (Leq). This tool facilitates for a designers to determine the existing noise on the research object. The working system of this tool is a to simplify the workings so that the obtained results is a round-off-error result of data series. The calculation use the statistical calculations and logarithms by entering the following formula (Szokolay, 2004).

$$\text{Interval} = \frac{\text{Max Value} - \text{Min Value}}{\text{total } (n)}$$

$$Leq = 10 - \text{Log} \left[ \sum \text{Freq} - 10 \frac{\text{Mtd}}{10} \right]$$

$$Leq_{\text{avg 24 hours}} = 10 * \text{Log} \frac{\sum T_n * 10^{0.1 * Leq(N)}}{\sum T_n}$$

Explanation :

Leq = Equivalent noise level (dBA)

N = Total Data

Mid = Median in interval class

Freq = Frequency

Tn = Period of measurement

Sound level is usually defined in terms of something called Sound Pressure Level (SPL). SPL is actually a ratio of the absolute, Sound Pressure and a reference level (usually the Threshold of Hearing, or the lowest intensity sound that can be heard by most people).SPL is measured in decibels (dB A), because of the incredibly broad range of intensities we can hear.

### Transmission Loss

Besides the impacts of airborne-sound factors itself, discussing about acoustics will also interact directly with the variables. The conducted research is indoor area research. This case might be determined with Transmission Loss.

Transmission Loss or abbreviated as TL is the value amount from the insulation of one or more partitions. The greater of losing value, the greater it will have an impact on the ability of material to insulate the existing sound (Hemond, 1983).

*TL value will be obtained by these following equations:*

$$TL = LS - LR + 10 \text{ Log } (Sw/R + 1/4)$$

$$NR = Ls - LR$$

$$TL = NR + 10 \text{ Log } (Sw/R + 1/4)$$

Explanation :

TL = Transmission loss

NR = Noice reduction

Ls = Average value of source

LR = Value of examined room

TL measurements are created in the frequency range of 125-4000 Hz (Doelle, 1985). These measurements can be conducted in a laboratory and measurements in the field. For laboratory measurements can be conducted with valid practices.

### **Acoustics Insulation**

Acoustics insulation is described as an important factor for the room comfort. On acoustics insulation must be considered that Noise Criteria (NC) from the building type and examined room type. It is important to know because every building and room have different functions. With the proper use of noise criteria, a good sound insulation will be obtained, so the comfort in the room can be achieved. Therefore, acoustics insulation material selection will be focused on the interior building, while for the exterior there are references for using shading and diffuser on the facade. In addition to the material used is a material fabrication that has been conducted before by experts.

### **Material Selection For Good Acoustics**

Material selection is certainly not an easy thing as it is seen. If an architect choose a material structure, he would have predicted how much noise will pass through the material. Selecting building envelope material should be examined also, how much noise will be reflected and how much sound will be absorbed.

Doelle (1985) stated that a sound absorption efficiency of material at a particular frequency is expressed by the sound absorption coefficient. Sound absorption coefficient of a surface is part of absorbed incoming sound energy, or not reflected from the surface. Hard and impenetrable interior surfaces, such as bricks, stone building materials and concretes, usually absorb an incoming sound waves energy less than 5% (0.05). On the other hand, the thickness of insulation absorbs incoming sound waves energy more than 80% (the absorption coefficient above 0.8).

For the materials used, as has been mentioned earlier that the materials used are fabrication materials. In addition, it is proven that using fabrication materials are

considered as a way to reduce the number of failures in inhibiting sound into the room. Fabrication materials which will be carried in this research are Brand Acourate. There are various offered materials, but are used and applied to the object of research is the type of fiber and board materials: Fiber 600, 800 and Fiber Board 230.

### Shading and Diffuser Form

Theoretically, the position of ventilation holes and doors that do not meet directly with the noise source will reduce the intensity of noise that enters into the building. However, the formula has not been found in particular way that can be used to calculate the amount of decreasing in intensity of hole position accurately. Mediastika (2005), through her observation showed that Jalousie's or Louvre's model window, especially with a layer of special materials are able to reduce the entry of noise that propagates along the air flow.

Jalousie window itself is made of aluminum or wood material. But so far, many aluminium materials are used by high rise building. The shape of the shading "Jalousie" can be seen in the Figure 1 below:



**Figure 1.** Illustrations of Shading Shape "Jalousie"

Source: author's documentation

According to the observations of the test jalousie models by Mediastika that the average of shading models such as the example in the figure above can reduce about 2-3 dB (Mediastika, 2005).

While the use of shading with Jalousie models, as has been mentioned in the background before that Picaut et al. (2010) presented a decrease noise significantly by considering the use of a diffuser on the facade. In his research, said that the diffuser is able to reduce the noise in the range of 500 - 1400 Hz. This matches with the train traffic condition where is in high frequencies. In addition, diffuser can be used either indoor or outdoor areas. For this research with case study of sahid Hotel, the diffuser can be used on the exterior facade of the hotel.

With the use of this diffuser, the experiment who was conducted by Picaut et al. (2010), showing a decrease of 5-10 dB. The use of the diffuser is also only about 45% of the total wall facade. Compared with the use of shading, this is a double great achievement. The benefits are not only the building aesthetics, but also the use of diffuser does not affect the quality of the view hotel (it refers to studycase). The

shapes of the diffuser which can be applied on the interior facade are as follows in Figure 2.



**Figure 2.** Illustration Form of Diffuser on Exterior Façade  
Source: author's documentation

### **Research Paradigm**

The paradigm in this research is the positivistic paradigm (Groat and Wang, 2002). This paradigm is necessary because this research is objective. The meaning of objective here is the results of this study are relevant with the data which are directly obtained from the field.

### **Research Methodology**

This research uses quasi experimental. These methods aim to determine the relation in variables of the research. Besides that, the experimental method can be achieved well if this research is conducted by using a combination of field and experiment observation. Meanwhile, to support the experiment can be achieved by using calculation method. So that both can complement each other in displaying the results that have been achieved.

The direct observation and measurement were done on the object of research has an important purpose which validation can be done internally and external (generalization to other similar conditions). While the experiments are aimed to achieve the goal of research, determining the appropriate material for acoustic insulation which is used for applying to the interior walls of a hotel room and set either an additional shading or diffuser which impacts the acoustic conditions inside the building.

While on the analytical calculations are using mathematical equations with the help of Microsoft Excel. It makes easier for calculating and minimizing the possibility of a miscalculation when using manual systems. Besides that, using the counting application materials as mentioned above, can speed up the process of calculation which has a lot of data characteristics (the research is complete within 2 x

24 hours). Beside that analytical methods use for decide to chose a reference of the use exterior wall diffuser which are suitable for outdoor area.

## Research Variables

To identify and explain the effect of material selection that has acoustics insulation and exterior facade shapes in order to increase the comfort of acoustics in buildings, they are distinguished into two interrelated variables. These variables are independent variables and the dependent variables. The explanations for these two types of variables are as follows:

1. Independent variable is a variable that can be modified in accordance with the conditions established in the case study object.
  - a. Existing Condition of the building  
The existing condition is Sahid Hotel Surabaya as a hospitality building located on a crowded area condition because it is located in the city center (located on East Surabaya). The distance between the train tracks and buildings are approximately 20 meters (Distance from sources of noise and affected buildings). The visitors' activity at Sahid Hotel is mostly in the form of breaks or meetings such as business meetings.
  - b. Architecture Dimension  
Calculation of building dimensions. In this case, the room that is measured its dimension is a bedroom of Sahid Hotel which closest to the railroad tracks. After making some observations, the preferred room type for this research is Twin Share Deluxe Room, located on the 4th floor.
  - c. Used Material Building  
Acoustic insulation material that is used is material "Fabrication" type.
  - d. Material Application On Interior Elements  
Walls that are for inside of the building interior, are divided into two types "Transparent and Non-Transparent". But the selection of insulation is more preferred on Non- Transparent walls, because the they have larger surface. For the transparent walls part, there will be a recommendation of Jalousie shading types. But how big the shading cover the transparent walls are still needed consideration, because it affects the "view" of the room. In addition, for exterior walls will be recommended by the diffuser.
    - 1.) Floor (aesthetics oriented, no effect on the calculation of Transmission Loss)
    - 2.) Ceiling (aesthetics oriented, no effect on the calculation of Transmission Loss)
2. Dependent variable is a variable that is affected by the independent variable. And this variable is variable that will be observed. And that will be examined in this case are:
  - a. Acoustics performance in the building, related to:
  - b. Transmission loss, and
  - c. Sound Pressure Level (SPL)

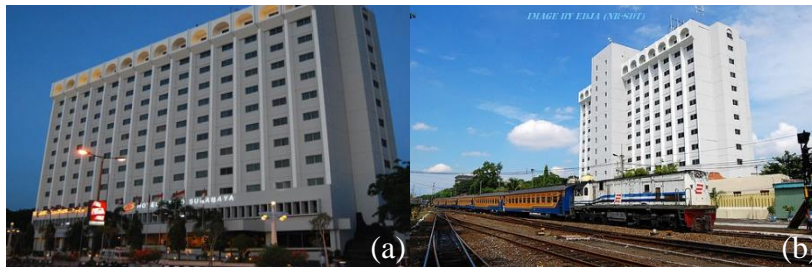


## Research Object

The determination of this object focuses on the research's results that will be conducted. Building that is observed in current research is hospitality building - Sahid Hotel Surabaya (Figure 3 and 4).



**Figure 3.** Existing Condition of Hotel Building with Its Surrounding Buildings  
 Note: A: Gubeng Railway Station B: Railway Track C: Sahid Hotel  
 Source: field survey



**Figure 4.** Building Facade of Sahid Hotel Surabaya  
 (a) Front Side and (b) Back Side  
 Source: field survey

The research will be focused on a bedroom located closest to the railroad tracks. In this case the room is located on the line of odd numbers. Because the room is directly opposite to the railway tracks is a room with an odd number. Besides that, the selection of floor level used is the 4th floor. This level is the lowest floor is used as a resting place for hotel guests. This selection is taken for getting optimum noise because it is very close to the sound source.

This room is usually for relaxation activities such as taking a rest, sleeping and relaxing (Figure 5).



**Figure 5.** Deluxe Room Twin Share Type Used for Research Object  
Source: field survey

### Data Retrieval Stage

Research object retrieval is the 4th floor of Sahid Hotel. It has its own reason because this floor is an area for visitors to relax. On the ground floor to the third floor are used for some other facilities such as lobby, meeting rooms, restaurant and rest area for playing billiards. While the basement area is used for offices and all kinds of administration Sahid Hotel.

Retrieval data is in one of the hotel room with the room number 4019. The position of the room can be seen in Figure 6. Position of room selection in the middle of the building is selected because the pollution noise comes from the train activities. The position of Sahid Hotel is located less than 100 meters from the Gubeng station. It has positive and negative noise impacts caused by trains. On the positive side the location of the hotel is close to the station. The noise is caused by the trains will not be optimal when it is compared to the train was speeding. On the negative side, the hotel position is close to the station. The Hotel will indirectly receive not only the noise caused by the train, but also other activities, such as warning sound for the arrival and departure of trains. For additional information, type of room that is used for data retrieval is Deluxe Room Twin Share Type (Table 1).



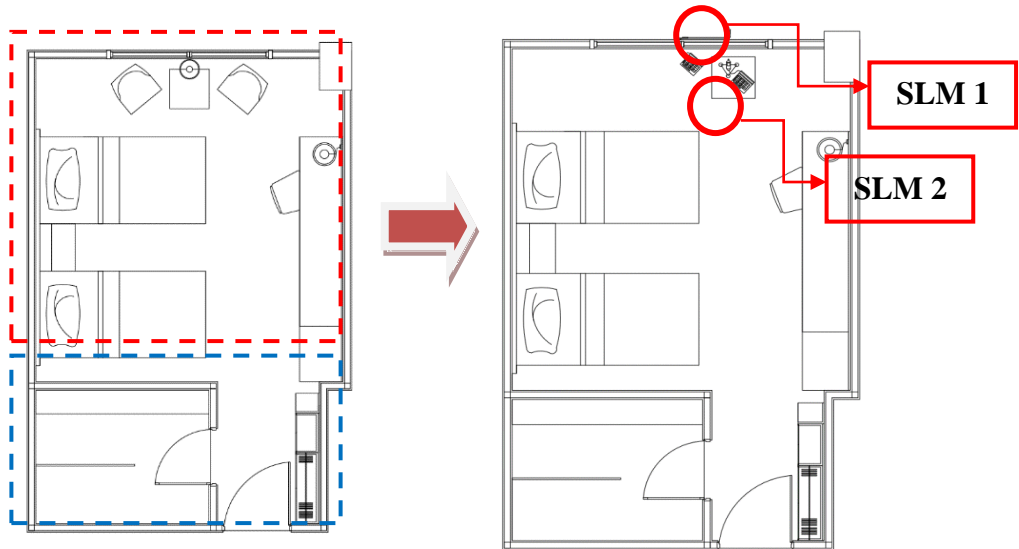
**Figure 6.** Layout of 4th Floor Hotel Sahid Surabaya  
Room 4019 is viewed in blue colour  
Source: field survey

**Table 1.** Dimensional of Deluxe Room Twin Share Type

| <b>L (Length)</b> | <b>W (Width)</b> | <b>H (Height)</b> |
|-------------------|------------------|-------------------|
| 6,00 meter        | 4,00 meter       | 2,90 meter        |

Source: field survey

After learning dimensions in general, the following section will discuss more specifically the interior condition of Deluxe Room Twin Share type. Figure 7 will describe the layout of Deluxe Room Twin Share.

**Figure 7.** Layout of Sahid Hotel Surabaya and Sound Pressure Level (SLM) Placement

Source: field survey

Red area is directly close to the rail. Sound sources from outside propagate through the air by passing through the slits from each window's room. While the area is underlined in blue is for a service area. Because the functions of a hotel room is for taking a rest, so the area which is always used is an area in the bedroom. This area is in the middle of the room. SLM 1 is a measuring tool that is placed outdoors, parallel with inside the room with distance of 20 cm from the window. While the SLM 2 is placed inside the room.

This research uses  $L_{eq}$  value calculation, because the noise source comes from the the railway activities that operate for 24 hours. The measurements were conducted twice with sample data retrieval on weekdays and holidays (weekend). The retrieval data in the second day was to determine if there are differences in the perceived noise for the hotel occupants with two different time conditions.

## RESULTS AND DISCUSSION

### Data Results from the Sound Pressure Level (SPL) of Sahid Hotel Surabaya

After calculating directly to the research object for twice twenty-four hours, the result is Sound Pressure level (SPL) in existing condition. The obtained data results describe two conditions, for working days (weekdays) and holidays (weekends). It was conducted to determine the differences in possible conditions due to differences in the activity of its users. Measurements were made using a Sound Level Meter (SLM), and then the data processing used Microsoft Excel to facilitate the SPL value (Figure 8).

|                | Hari   | Jam      | SPL (IN) | SPL (OUT) |                | Hari     | Jam      | SPL (IN) | SPL (OUT) |
|----------------|--------|----------|----------|-----------|----------------|----------|----------|----------|-----------|
| <b>WEEKEND</b> | Sabtu  | 18.00    | 52.88517 | 73.57914  | <b>WEEKDAY</b> | Senin    | 01.00    | 47.82799 | 69.0857   |
|                | Sabtu  | 19.00    | 57.5573  | 76.5627   |                | Senin    | 02.00    | 56.05031 | 68.20149  |
|                | Sabtu  | 20.00    | 55.91746 | 71.07116  |                | Senin    | 03.00    | 56.34028 | 72.28542  |
|                | Sabtu  | 21.00    | 55.95554 | 70.07361  |                | Senin    | 04.00    | 56.67995 | 74.18018  |
|                | Sabtu  | 22.00    | 56.36127 | 73.62006  |                | Senin    | 05.00    | 57.43554 | 63.7461   |
|                | Sabtu  | 23.00    | 56.04604 | 70.75092  |                | Senin    | 06.00    | 57.8875  | 64.39323  |
|                | Sabtu  | 24.00    | 55.8254  | 69.84605  |                | Senin    | 07.00    | 57.55682 | 63.71531  |
|                | Minggu | 01.00    | 55.52518 | 64.26148  |                | Senin    | 08.00    | 57.11216 | 73.17098  |
|                | Minggu | 02.00    | 55.4357  | 68.9544   |                | Senin    | 09.00    | 56.45366 | 69.44462  |
|                | Minggu | 03.00    | 55.24093 | 64.69644  |                | Senin    | 10.00    | 55.59462 | 69.71555  |
|                | Minggu | 04.00    | 57.63474 | 75.96603  |                | Senin    | 11.00    | 56.86075 | 73.68054  |
|                | Minggu | 05.00    | 56.53386 | 69.59676  |                | Senin    | 12.00    | 57.58216 | 72.0891   |
|                | Minggu | 06.00    | 55.54771 | 69.21833  |                | Senin    | 13.00    | 55.49846 | 69.82401  |
|                | Minggu | 07.00    | 55.30382 | 69.30461  |                | Senin    | 14.00    | 56.25781 | 67.96202  |
|                | Minggu | 08.00    | 56.59508 | 64.05001  |                | Senin    | 15.00    | 55.99227 | 64.14656  |
|                | Minggu | 09.00    | 55.82801 | 71.11078  |                | Senin    | 16.00    | 56.52504 | 71.1254   |
|                | Minggu | 10.00    | 55.85179 | 70.50232  |                | Senin    | 17.00    | 55.93074 | 73.74893  |
|                | Minggu | 11.00    | 54.82484 | 71.38974  |                | Senin    | 18.00    | 56.3852  | 69.08543  |
| Minggu         | 12.00  | 56.70675 | 70.19238 | Senin     |                | 19.00    | 55.89936 | 69.52805 |           |
| Minggu         | 13.00  | 55.31804 | 71.24329 | Senin     |                | 20.00    | 56.69634 | 72.06825 |           |
| Minggu         | 14.00  | 55.85425 | 69.58864 | Senin     |                | 21.00    | 58.69183 | 68.64944 |           |
| Minggu         | 15.00  | 55.72219 | 69.2439  | Senin     |                | 22.00    | 57.30005 | 63.97983 |           |
| Minggu         | 16.00  | 55.22845 | 79.32939 | Senin     |                | 23.00    | 56.76059 | 63.09899 |           |
| Minggu         | 17.00  | 57.66336 | 75.28751 | Senin     |                | 24.00    | 57.83467 | 68.45146 |           |
| Minggu         | 18.00  | 54.7411  | 71.90463 | Selasa    | 01.00          | 57.91279 | 68.41056 |          |           |

Figure 8. SPL Value for Both Conditions

Source: analysis results

Table 2. Noise Average on Weekends

| Noise Average on Weekends (Day-Off) |                                  |
|-------------------------------------|----------------------------------|
| Inside the building                 | Outside (near from noise source) |
| 55.89 dB (A)                        | 70.47 dB (A)                     |

Source: analysis results

Weekend - Sunday (16:00 PM), with acoustic noise peak outside which amounted to 79 dB. While for inside the room the noise peak is on Saturday at 19:00

and Sunday at 04.00 and 17.00 pm, at these conditions reach the level of noise at 57 dB (Table 2).

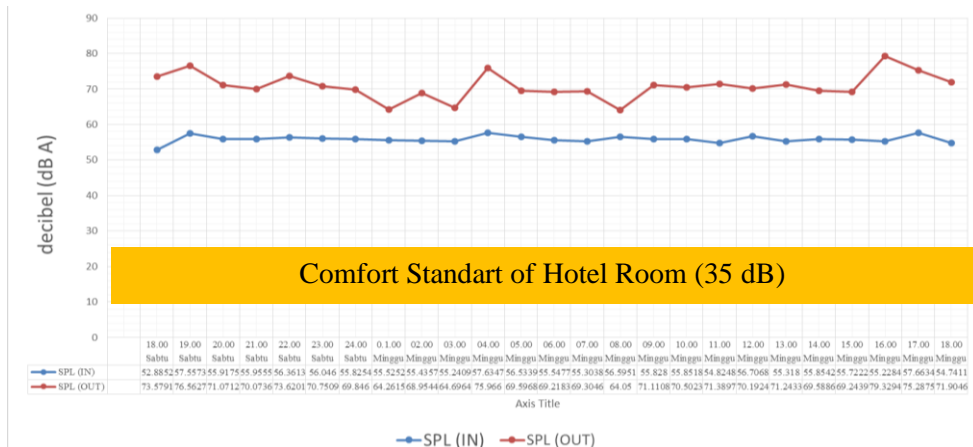
**Table 3.** Noise Average on Weekdays

| Noise Average on Weekdays (Working Days) |  |
|--|--|
| Inside the building<br>56.86 dB (A)      | Outside (near from noise source)<br>68.57 dB (A) |

Source: analysis results

Weekday - Monday (16.00) with a acoustics noise peak outside at 74 dB. The noise peak conditions inside Sahid Hotel is at 57 dB, someone of them on Tuesday at 01.00 which is 57.9 dB (Table 3).

The calculation result of noise in the hotel room has exceeded the standards (Table 4), Figure 9 below explains about it. It appears that on the weekend, the condition of inside the building has exceeded existing standards.



**Figure 9.** Leq on Holiday (Weekend)  
Source: analysis results

**Table 4.** Table Noise Level (Koenigsberger, 1973)

| Building | Room           | dB (A) |
|----------|----------------|--------|
| Dwelling | Bedroom, house | 25     |
|          | Bedroom, flat  | 30     |
|          | Bedroom, hotel | 35     |
|          | Living room    | 40     |

Source: analysis results

On the working days, is also seen that the noise has exceeded the existing limits. It can see more detail in Figure 10 below.

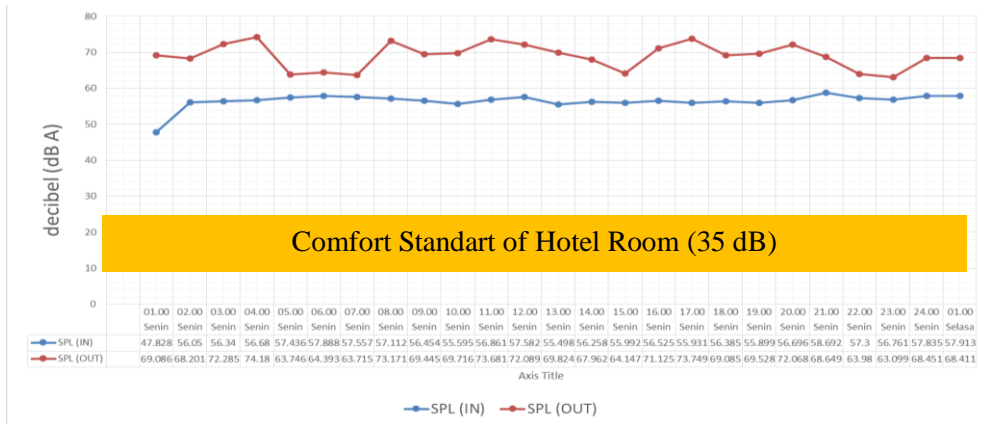


Figure 10. Leq on weekdays  
Source: analysis results

On working days or weekdays condition, noise that occurs in the building have similarities condition on weekend. The noise condition is between 50-60 dB. While the noise neighborhood is in the range of 62-78 dB.

### Material Selection of Existing Walls

After knowing and how much the leakage occurs, the next stage is to start choosing the right insulation material. The materials need to be selected carefully because they are critical success factor of this research. To design an appropriate existing wall of Sahid Hotel Surabaya, first we should know the noise level of each frequency. As an information that the threshold of human hearing is at level of 20-20000 Hz, but to determine all noise types that generated by the trains, it can be explained in all ranges, recorded by the SLM. To get the value of sound level, it can be calculated using the following formula:

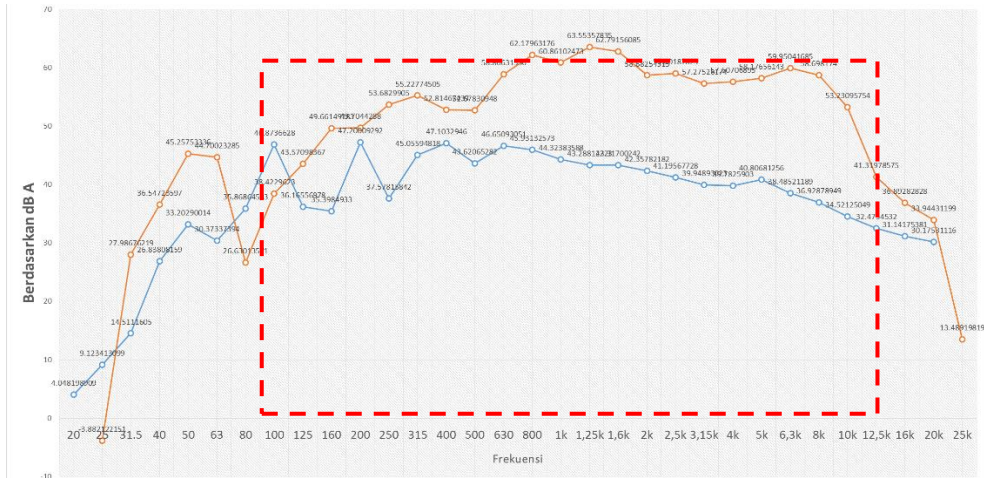
$$Li = 10 \log I/Io \text{ dB}$$

Explanation:

- Li = sound intensity level, dB
- I = sound intensity, W/m<sup>2</sup>
- Io = reference sound intensity, 10-12 W/m<sup>2</sup>

The calculation above is to produce an average noise intensity level at each frequency. The data have been taken within 2x24 hours. The range of data collection is in ten minutes to represent in every hour. Every ten minutes represent sixty data. So in one minute represents six data. Each data in every hour will be taken the average to process the data using Microsoft Excel in order to get a graph below (Figure 11).





**Figure 11.** Graph of Sound Level Value (dB) Inside (blue) and Outdoor (red) Room at Each Frequency  
Source: analysis results

The obtained sound level value on the figure above explains that train noise is a kind of high-frequency noise. The selected standard frequencies that can be chosen as an important role in the acoustic environment are 125, 250, 500, 1000, 2000, and 4000 Hz or 128, 256, 512, 1024, 2048, and 4096 Hz (Doelle, 1985).

The graph above, the highest frequencies are at 630 -1600. The graph modifications will be focused on those frequencies (Table 5).

**Table 5.** Existing Noise Indoor and Outdoor Calculation of Research Object

|  |     | Frequency |      |      |      |      |      |       |      |      |      |       |
|--|-----|-----------|------|------|------|------|------|-------|------|------|------|-------|
|  |     | 315       | 400  | 500  | 630  | 800  | 1k   | 1,25k | 1,6k | 2k   | 2,5k | 3,15k |
|  | IN  | 52,8      | 52,6 | 58,8 | 61   | 60,8 | 63,5 | 6,7   | 58,6 | 59   | 57,2 |       |
|  | OUT | 47,1      | 43,6 | 46,6 | 45,9 | 44,3 | 43,2 | 43,3  | 42,3 | 41,1 | 39,9 |       |

Source: analysis results

According to the previous determination, the highest frequency is at 630 Hz - 1600 Hz, so the noise reduction is focused in these frequencies.

After determining the frequency, then the next stage is the modification. In this research, there are five modifications, as described in the Table 6:

**Table 6.** Existing Materials and Modification Materials

| Existing   | Modifiction 1                       | Modifiction 2                       | Modifiction 3                   | Modifiction 4   | Modifiction 5   |
|--|-------------------------------------|-------------------------------------|---------------------------------|---|---|
| Materials:<br>Walls with<br>plaster<br>Transparent<br>glass, thick-<br>nes 2,5-3<br>mm | Materials:<br>Acourete Fiber<br>600 | Materials:<br>Acourete Fiber<br>800 | Materials:<br>Acourete<br>Board | Materials:<br>Acourete Fiber<br>800<br>(75%) and<br>Acourete Board<br>(25%) | Materials:<br>Fiber 800<br>(25%) and<br>Acourete Board<br>(75%) |

Source: analysis results

## Analysis

As already known, human hearing frequency range is at 20-20000 Hz. The above table shows the average amount of noise at each frequency, where the frequency of 630-1600 Hz is the highest noise. At these frequencies, noise is at 45dB. Of course, it is exceeded the limits of comfort for the hotel room. But before applying room material for comfort, the sound pressure level are checked by calculating the existing building.

Existing data checking is by adjusting the conditions in the field. Noise transmission walls that occurs at Sahid Hotel Surabaya is 11.6 m<sup>2</sup>, which consists of a brick wall of 9.2 m<sup>2</sup> and window area of 2.4 m<sup>2</sup>. The composition of the wall is brick with a layer of white paint while the window with a thickness of about 2-3 mm. At this stage, the modifications will be expalained in order to improve the building insulation acoustic.

## Modifications of Acoustic Insulation Material

### Acourete Fiber 600

Fiber Material produced by Acourete with density values of 600, made of polypropilene, is be able to absorb up to ten times better than other dampers. The width and thickness dimension are 1.5 meters and 4 mm. After the calculation using formula value of indoor sound pressure level of the existing condition, then it is obtained in Table 7.

**Table 7.** Modification Result 1

| Frequency                | 630      | 800      | 1000     | 1250     | 1600     |
|--------------------------|----------|----------|----------|----------|----------|
| SPL Outside (dB)         | 58,86632 | 62,17963 | 60,86102 | 63,55358 | 62,79156 |
| Modification Result (dB) | 38,00415 | 38,7921  | 35,70506 | 36,55308 | 33,66246 |
| Standart (dB)            | 30-35    | 30-35    | 30-35    | 30-35    | 30-35    |
| SPL Inside (dB)          | 46,65093 | 45,93133 | 44,32384 | 43,28812 | 43,317   |

Source: analysis results



From the results of the first modification, it is obtained significant results from decreasing in the inside of building. When compared with the previous one, there has been decreased of 8-10 dB. From 46.65 dB to 38 dB. However, these values are mainly still above the upper threshold of standard for noise-room hotel, but a frequency of 1600 Hz is at threshold.

### Acourete Fiber 800

Various fiber materials provide the option in its use. This second modification covers the walls with fiber with a thickness of 8 mm.

**Table 8.** Modification Result 2

| <b>Frequency</b>                | <b>630</b>      | <b>800</b>      | <b>1000</b>     | <b>1250</b>     | <b>1600</b>     |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| SPL Ouside (dB)                 | 58,86632        | 62,17963        | 60,86102        | 63,55358        | 62,79156        |
| <b>Modification Result (dB)</b> | <b>33,10276</b> | <b>34,11186</b> | <b>30,97753</b> | <b>31,89181</b> | <b>29,03804</b> |
| Standart (dB)                   | 30-35           | 30-35           | 30-35           | 30-35           | 30-35           |
| SPL Inside (dB)                 | 46,65093        | 45,93133        | 44,32384        | 43,28812        | 43,317          |

Source: analysis results

The thickness has an influence in transmitting sound. In this case, the fiber layer is thicker. It supported by the density of each material. If the density is as good as the material thickness, it is able to produce a good composition in order to create a comfortable room. It can be seen in the Table 8, the noise can be overcome well.

### Acourete Board 230

A permeable damping material is in softboard form. The material is usually made of solidified polyester which. This material has a density of 230 kg / m<sup>3</sup>. The results of its application are presented in Table 9.

**Table 9.** Modification Result 3

| <b>Frequency</b>                | <b>630</b>      | <b>800</b>      | <b>1000</b>     | <b>1250</b>     | <b>1600</b>     |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| SPL Outside (dB)                | 58,86632        | 62,17963        | 60,86102        | 63,55358        | 62,79156        |
| <b>Modification Result (dB)</b> | <b>43,58413</b> | <b>45,10877</b> | <b>42,54401</b> | <b>43,49544</b> | <b>40,79759</b> |
| Standart (dB)                   | 30-35           | 30-35           | 30-35           | 30-35           | 30-35           |
| SPL Inside (dB)                 | 46,65093        | 45,93133        | 44,32384        | 43,28812        | 43,317          |

Source: analysis results

From the data above, it can be seen that the performance of Acourete board 230 has successfully reduced the value of the sound pressure level. It is better than the existing condition, but it is still far from standard level.

From these three materials selection, it is obtained a combination by coating the surface wall with fiber layer 600. It can bring quiet and comfortable atmosphere

in rooms. While the unoptimal result is in the third combination result using board panel. The comparison can be seen in the Table 10 below:

**Table 10.** Combination Results with Fabrication material

| <b>Frequency</b>   | <b>630</b> | <b>800</b> | <b>1000</b> | <b>1250</b> | <b>1600</b> |
|--------------------|------------|------------|-------------|-------------|-------------|
| Acourete Fiber 600 | 38,00      | 38,79      | 35,70       | 36,55       | 33,66       |
| Acourete Fiber 800 | 33,10      | 34,11      | 30,97       | 31,89       | 29,03       |
| Acourete Board     | 43,58      | 45,10      | 42,54       | 43,49       | 40,79       |

Source: analysis results

After applying these three material shows that the best acoustic insulation is the second type of modification by Fiber 800. The first modification has a significant decreasing result of inside building. However, these values are still in the upper of threshold criteria for noise standard hotel room, but frequency of 1600 Hz is in the upper threshold for comfort.

But the price of fiber material is much more expensive than the board. To cut the operations price, redesign planning can be done with other methods combination of both materials. With the combination of both, it is expected to get good values that is close to the first value. The combination can be conducted by material configuration. Below is a table that explains configuration results of fiber material and the board to be applied to the hotel room interior walls.

### Material Configuration 1 Fiber 800 and board 230

This modification of acoustic insulation is 75% using fiber 800 and the rest is 25% using board 230. The results are quite satisfactory with a range of 35 dB for the noise in the building (see Table 11).

**Table 11.** The Result of Modification 4

| <b>Frequency</b>         | <b>630</b> | <b>800</b> | <b>1000</b> | <b>1250</b> | <b>1600</b> |
|--------------------------|------------|------------|-------------|-------------|-------------|
| SPL Outside (dB)         | 58,86632   | 62,17963   | 60,86102    | 63,55358    | 62,79156    |
| Modification Result (dB) | 37,2623    | 38,22521   | 35,07465    | 33,10132    | 27,18605    |
| Standart (dB)            | 30-35      | 30-35      | 30-35       | 30-35       | 30-35       |
| SPL Inside (dB)          | 46,65093   | 45,93133   | 44,32384    | 43,28812    | 43,317      |

Source: analysis results

This modification results provide an additional information in the acoustic insulation selection, by modifying both materials to improve one of material performance.

### Material Configuration 2 Fiber 800 and board 230

This modification is still using the same materials with previous modifications, but differentiation here is the amount of the composition of each material. The percent-

ages are 75% using Board 230 and 75% using fiber 800. The result can be seen in the Table 12 below:

**Table 12.** The Result of Modification 5

| <b>Frequency</b>                | <b>630</b>     | <b>800</b>     | <b>1000</b>    | <b>1250</b>    | <b>1600</b>    |
|---------------------------------|----------------|----------------|----------------|----------------|----------------|
| SPL Outside (dB)                | 58,86632       | 62,17963       | 60,86102       | 63,55358       | 62,79156       |
| <b>Modification Result (dB)</b> | <b>41.6121</b> | <b>42.4178</b> | <b>39.1989</b> | <b>40.0055</b> | <b>37.0952</b> |
| Standart (dB)                   | 30-35          | 30-35          | 30-35          | 30-35          | 30-35          |
| SPL Inside (dB)                 | 46,65093       | 45,93133       | 44,32384       | 43,28812       | 43,317         |

Source: analysis results

There is a significant difference when the percentage was changed from 25% of fiber and 75% of board. There is a noise reduction than before, but the room is still exceeded the permeable noise with a threshold of 35 dB.

It shows that the noise control is in the fiber material. It is capable to improve comfort inside the building. So, it is in accordance with the recommended standard.

While from five modifications made, it is obtained a result as the Table 13 below:

**Table 13.** The Results of All Modifications (five modifications)

| <b>Frequency (Hz)</b> | <b>630</b>     | <b>800</b>     | <b>1000</b>    | <b>1250</b>    | <b>1600</b>   |
|-----------------------|----------------|----------------|----------------|----------------|---------------|
| Fiber 600 (dB)        | 38.0041        | 38.7921        | 35.7051        | 36.5531        | 33.6625       |
| Fiber 800 (dB)        | <b>33.1028</b> | <b>34.1119</b> | <b>30.9775</b> | <b>31.8918</b> | <b>29.038</b> |
| Board (dB)            | 43.5841        | 45.1088        | 42.544         | 43.4954        | 40.7976       |
| Combination 1 * (dB)  | 37.2623        | 38.2252        | 35.0747        | 35.9666        | 33.1013       |
| Combination 2 ** (dB) | 41.6121        | 42.4178        | 39.1989        | 40.0055        | 37.0952       |

Source: analysis results

It can be seen in the table above that the use of insulation material with a single fiber type 800 is in first position in terms of noise reduction. Then in the second position is a combination of fiber material 800 and the board 230 with a percentage of 75% using fiber material and 25% using 230 board material.

### **Shading and Diffuser for Building Exterior Facade Reference**

There are several ways of using an acoustic insulation that can be used to reduce noise in the building. One of them are the use of shading on windows. Mediastika (2005) explained that the use of window model "jalousie" can reduce noise 1-3 dB. This study was then developed by Prianto et. al. (2014) concerning the observation window double-leaved on a building which produces significant noise reduction. The experiment informed that the use of double-glazed with permanent glass win-

dows combination and coupled grating "jalousie" produced a sufficient noise which is equal to 5 dB.

Other solutions which can be applied to the exterior facade is the use of wall diffuser. Picaut et al. (2010), in his study explained that there is a significant noise decline when it is observed through simulation by using a diffuser which is applied to the walls of the building. For the building condition, in previous study, it is conducted in buildings affected by highway noise.

Through this research, the decline is at 30-35% than before. The simulation also shows that it is suitable applied in solid areas. This is in accordance with the conditions of Sahid Hotel where located in the city center with building position near the railroad tracks. The result of that reducing, using the diffuser at 35% that covers the building walls. This means that the wall without diffuser is able to provide a noise reduction. With the condition of Sahid Hotel that consists of transparent and non-transparent, the diffuser is the solution is solution and it can be applied. Other things that can be learnt from the Sahid Hotel is is the diffuser does not affect the view quality of the hotel. Many hotels offer a good view to attract customers, such as the Sahid Hotel who has a view of the train tracks and stations. They are not far from the hotel (less than 100 meters).

The principle use of this diffuser is to reflect the sound which will come into the building. It has a same function with shading, diffuser also has other benefits, namely as the aesthetics of the building. The addition of this diffuser makes the building looks more attractive. It would be very nice if the interior of Sahid Hotel uses an acoustic insulation and the exterior uses diffuser. So the obtained results are the condition of a comfortable hotel room standards, and from the architectural side, the hotel shows its aesthetic impression but still pays attention on the acoustic conditions inside the building. the diffuser can be applied on the building facade in vertical as well as horizontal. However the use of horizontally where gives a positive effect for reducing the noise of the outside environment. With calculation can inform that the use of a diffuser horizontally can reduce noise by 30, 75 percent with application materials diffuser in the amount of 40 percent on the exterior facade of the building (Table 14).

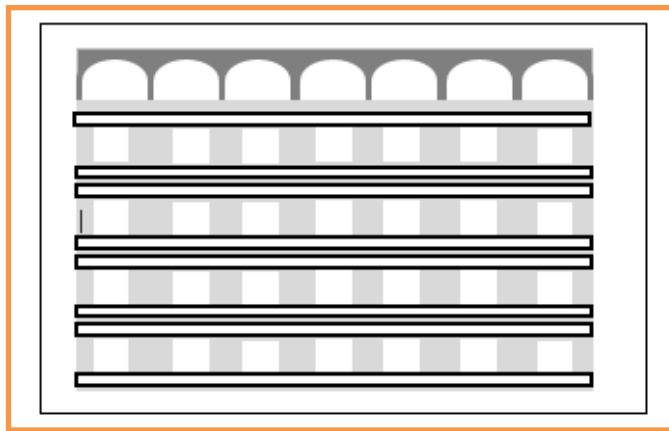
**Table 14.**The Results of the Calculation of the Use of a Diffuser to Reduce Noise

| No | Percentage of Diffuser Cover Surface Areas of the Surface | The Surface Area Covered with a Diffuser | The Surface Area of The Walls (Hotel Sahid) * | Noise Reduction |
|----|---|--|---|-----------------|
| 1  | 10 %  | 208,8 m <sup>2</sup>                     | 2088 m <sup>2</sup>                           | 7,5 %           |
| 2  | 20 %  | 417,6 m <sup>2</sup>                     | 2088 m <sup>2</sup>                           | 15 %            |
| 3  | 30 %  | 626,4 m <sup>2</sup>                     | 2088 m <sup>2</sup>                           | 22,5 %          |
| 4  | 40 %  | 835,2 m <sup>2</sup>                     | 2088 m <sup>2</sup>                           | 30 – 35 %       |
| 5  | 50 %  | 1044 m <sup>2</sup>                      | 2088 m <sup>2</sup>                           | 30,7 %          |

Source: analysis results

After knowing the function of the diffuser and the resulting performance of the application diffuser on exterior walls, the next step in this research is giving an

idea in applying to the building Sahid Hotel Surabaya. The figure can be drawn by using Sketch Up as building illustration media in Figure 12.



**Figure 12.** Diffuser Application on the Facade Exterior of Hotel Sahid Surabaya  
Source: analysis results

## CONCLUSIONS

Based on the research that has been done, it can be concluded as follows:

1. The condition of the existing walls of the bedroom 1 Sahid Hote Surabaya is still not able to reduce the noise caused by the noise of the surrounding environment. Where the noise is strengthened by the direct calculations results and the results have exceeded the standard of building comfort, especially in hospitality building types such as Sahid Hotel Surabaya. So, from this condition should redesign to improve the acoustic insulation of the facade wall.
2. The best design for this time is the wall material combined with fiber brand Acourete 800, because one of the real example is a frequency of 1000 Hz with SPL values 60 dB that can reduce the noise, so SPL is at 30 dB. These conditions increase the comfort in the room. The noise also does not also exceed the limit which is equal to 30 dB above the threshold of 35 dB.
3. Fiber material is a material fabrication with thinner thickness dimension compared to other acoustic insulation. And the usage does not take up much space, so the space volume is still maintained. Because it is a kind of material fabrication, it is created by experts, from price side is quite expensive. But the results are very good. Beside that, the installation is easy and fast, it is possible that this material will be a material for future reference.
4. Another design reference is the use of a diffuser on the exterior facade of the building because it can reduce noise by 30-35%. The use of this diffuser will not also interfere the view that is offered to guests.

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