A Study of Noise Level in Churches due to Outdoor Sound

by Sangkertadi 6

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Abstract

The purpose of this study is to determine the acoustical contribution of walls, architectural interior, and distance of Churchesbuilding from the road in order to reduceindoor noise. Two church buildingswere as cases: the Church of Sam Ratulangi University and the Bethesda Ranotana Church in Manado City, Indonesia. A motorcycle as sound source was placed outside the room near the fence. The sound source was varied from 60 to 100 dB. Sound received was recorded, calculated, and measured at distance every 2 m at outside and inside. Sound measurement was done by using a Sound Level Meter. Calculations were done by acoustics theory and I_Simpa software.Object of calculation areinitial design and its proposed design improvement. By applying a sound source of 100 dB, through measurements, it can be obtained indoor sound level of 67.1 dBfor case of Sam Ratulangi University Church, and 58.8dB for case of Bethesda Ranotana Church.Graphical visualizations of sound distribution by I_Simpa software, show role of doors and opened windows that cause outdoor sound penetration into the room.Based on the results of the design improvement, it can achieve a better indoor acoustic quality, even it can not exceed the maximum indoor noise criteria for churches as mentioned in the national standard, which is less than 35 dB.

Keywords: noise, outdoor, indoor, church

1. Introduction

It is not easy to avoid the outdoor noise penetration into indoor of buildingswhere the site of the building is atfront of the road with a heavy traffic volume. Noise is also included in the category of environmental pollution that is harmful to health and has often occurred [3] [17]. In general noise pollution from automobile transport has a sufficient negative impact on the environment of urbanized territories [13]. There are many of buildings had designed with the concept of natural ventilation that apply wide openings for ventilation effectivity, but its have impact on the transmission of noise that enter the rooms through windows and open doors. This is the problem that needs to be studied, to find out such design solutions in order to reduce noise that enter the room. At first it is necessary to know how much the level value of outdoor sound intensity that penetrate the opening of the wall or building façade.Wide opened windows that installed at walls are indeed at risk of receiving external environmental noise and disrupting communication in room [18]. Appliances like air-conditioners, ceiling fans, electrical switches and shoe noise also contribute to the noise generation problem within the auditorium. It is noted that the volume of noise produced by these appliances can be highly disturbing. Door openings and windows as well as the movement of furniture also contribute to noise generation within the church auditorium [5].

In this study, an acoustical research was carried out regarding the noise entering the two worship buildings, namely the Church of Sam Ratulangi University and the Bethesda Ranotana Church, in Manado City, Indonesia (Figures 1 and 2). Those two churchs were chosen because they are located near from road. The traffic of the road has potentiality to cause environmental noise withinthe church rooms. In addition, the distances from the buildings to the side ofthe road are relatively not far, which are about 10 m. The two churches are designed based on the concept of natural ventilation with applyingsome wide openings for entering fresh air from outdoor. The devices of ventilation openings risk transmitting noise from outside. The walls are made of masonry plastered with cement and painted white colour. At the yard there are some grass, trees, and flower plants, but they are not quite dense. Worship buildings such as churches need to be protected against the risk of noise, because the noise will disturb the solemnly of the people in carrying out the worship process. Interior room of Church worship buildings, must meet a maximum indoor noise standard of 35 dB (following to Indonesia standard SNI 03-6386-2000). In the other side there are results of studies indicate that sound from inside of the churchs may also cause environmental outdoor noise pollution to the surrounding [1] [6] [2]. Some of certain situation in general show that increasing the volume of indoor sound may be necessary to counteract outside noise.

Apart from the limitation of noise in the church, there is also a requirement for reverberation time figures (in seconds) for rooms with church functions. Referring to the Indonesian Standard, SNI 03-6386-2000, the value of RT for a prayer room is 1.6 to 2.6 seconds. The larger the RT value, the greater the echo in the room, and this will not be comfortable for worship. However, certain echo sounds are still needed for the needs of the worship procession. In general, the size of the reverberation time is determined by the material properties of the room interior which is able to absorb sound, therefore there is no excessive reflected sound.

Even the building has some openings, but such configuration of open window may reduce noise from outdoor. Window that is not fully opened is still expected to get a fairly good noise reduction. Mediastika [14] conducted a laboratory experiment to determine the opportunity for an open window to reduce noise. The results show that windows which are opened with tilt angle of 10 degrees are still able to reduce 5 dB. Meanwhile, if the tilt is only 5 degrees, it can reduce by 7 dB. A study by Du [4] on noise reduction due to glass ventilation with a permeability of about 20%, show that there is an opportunity of noise reduction of around 8 to 12 dB depending on the octave that be applied. While the results of research from Barbara Locher et al [10] regarding the transmission loss of open windows in apartments, show the results that noise reduction can occur by 10 dB in room where the interior has not good sound absorption.

A study on the noise reduction of the envelop wall system of hotel rooms equipped with glass windows that are not too wide, about 50% of the associated walls, located close to the railway, can show a noise reduction rate of about 12 to 15 dB [9]. On the inside wall of the hotel room have been equipped with a layer of sound-absorbing material, with objective to reduce indoor noise. The sound absorption properties of the material in the room contribute to the reduction of indoor noise.

In this study, architectural configuration of the window openings at both Churchs, are about 30% of itswallcorresponding. Usually the windows are fully opened when there is activity of worship in the inside for getting a good air ventilation from outdoor. According to the results of the studies by researchers that has mentioned above, this opening configuration hypothetically can not significantly reduce the noise. However, through this research, the goal is to know the magnitude of noise reduction that occur in the case of the both churchs. This is to know how much noise reduction due to the distance of the builidng to the sound source at road, as well as the role of window openings and the interior. The result of this study may then lead to the conclusion whether the room in the church has met the maximum noise standard requirements or not. In addition, by this study the pattern of the contour lines of sound propagation from the outside to the inside will also be known, in order to guide the practical work to increase quality of indoor acoustic.

Furthermore, based on the results of measurements and calculations of acoustic quality of the existing conditions, an evaluation was carried out. Based on the evaluation results, it can be proposed an interior design improvement in order to achieve a better indoor acoustic quality.

Figure.1. Church of Sam Ratulangi University

Figure.2. Church of Bethesda Ranotana, Manado

2. Methodology

The study used quantitative method, by applying field measurements, calculations by using spread sheets and application of aprogram package (software).

2.1. Measurement

In the process of measuring the sound intensity, researchersused Sound Level Meter equipment used to measure the level of sound loud in dB(A). Sound of a motorcycle's engine was usedas the sound source and placed at road. It sound level was be set at 60, 70, 80, 90, and 100 dB, with a tolerance of about 5%. The value of 100 dB was applied as the maximum sound intensity level whichconsideresto the standard of horn sound thatrefer to PP No. 55 of 2012 (Indonesia regulation on vehicle). In the regulation mentions that the lowest level of the sound of horn is 83 dB(A) while the highest is 118 dB(A). The sound source by a motorcycle engine located on the road was tuned to a constant sound level. Then measured the level of received sound at every 2 m distance. Measurements with a sound level meter were taken from outdoor area until the center of room (Fig.3 and 4).The digital Sound Level Meter was positioned height 1.5 m from the land or floor. The measurement method also refers to Appendix II of the Decree of the Minister of Environment of Indonesia KEP-48/MENLH/11/1996.

2.2. Calculation

Calculation of noise reduction due to the distance factor (between the sound source and receiver) was conducted, and following the general formula of sound propagation that based on a spherical sound distribution pattern. The general equations of acoustic theory on sound propagation and sound intensitylevel are as follows [15]:

$$I_1 = \frac{P}{4\pi(r_1)^2};\ I_2 = \frac{P}{4\pi(r_2)^2}\ ;\ I_n = \frac{P}{4\pi(r_n)^2},;\ \text{and } IL = 10\ log\ \frac{I}{I_o};\ (1)$$

$$\Delta IL = IL_2 - IL_1 = 10\,log\frac{I_2}{I_o} - 10\ log\ \frac{I_1}{I_o}(2)$$

where I is the sound intensity, and r is the distance from receiver to the sound source, P is the sound power and IL is the sound intensity level. Meanwhile, noise reduction in the building by sound absorption factor of the receiving room and due to sound sources in attached rooms can be estimated through the general formula of Noise Reduction (NR) [15] as follows:

$$NR = IL_1 - IL_2 \qquad (3)$$

$$NR = SRI - 10\,log\frac{A_S}{\sum A_{i(2)}a_{i(2)}} \qquad (4)$$

where IL_1 is the outside sound intensity level, IL_2 is the indoor sound intensity level; SRI is Sound Reduction Index of the separation wall and $a_i$is the coefficient of sound absorption of the surfaces in receiving room, A_i is the area of the wall surface in the receiving room. A_s is the separation wall area.
The measurement results of IL_1 and IL_2 are then will be used as input in the calculation process to obtain the amount of NR and SRI.
Apart from the formulation as a factor to counteract noise from outside sounds in the room, the reverberation time number (RT, in seconds) must be adequate or in accordance with the function of the room. The formula for calculating the reverberation time is as follows [20]:

$$RT = \frac{1}{6}x\frac{V}{\sum aA} \qquad (5)$$

Where V is the volume of room (in m^3), a is sound absorption coefficient of a surface, A is area of the surface (in m2).

2.3. Simulation with I_Simpa . Program

I_Simpa is a program package for calculating and visualizing the distribution of sound propagation. In this study, it was used to compare the results of calculations (manual) and to the results from measurements, as well as to visualize the contour line pattern of the sound spread from outside to the worship room.

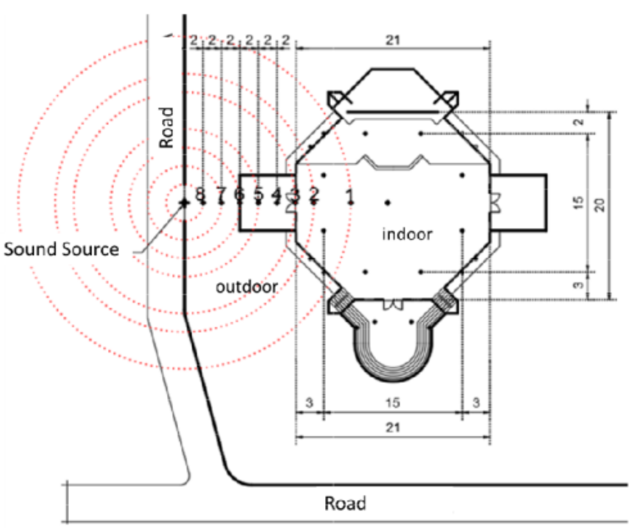

Figure.3. Plan of Church of Sam Ratulangi University, Manado

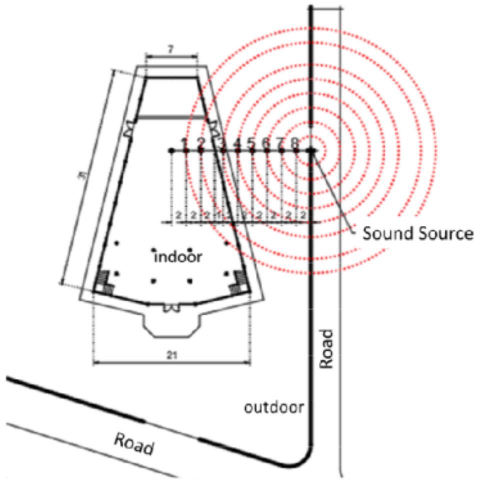

Figure.4. Plan of Bethesda Ranotana Church, Manado

3. Results and Discussion

3.1. Analysis of Existing Condition

The measurement results show a significant decrease of sound intensity from the sound source at outside to the inside. Both of the two church buildings show a same tendency. Results of the measurements at the Church of Sam Ratulangi University are shown in the Fig.5. By applying a sound source of 100 dBA at road, it was shown a normal graph, where the sound intensity was decreased non linearity along the distance from source until indoor the church. An anomaly graph was found at distance from 2 to 4 meters when the sound source was changed to 70 and 90 dbA. The sound intensities were recorded very low at distances 2 and 4 m from the source, and increase at distance 6 m, and then decrease normaly until indoor. This anomaly sound intensity can occur due to other background noise that can not be intervented by researchers, like sound of wind, birds, people, or cars and other motorcycles that pass the road. The other background sound can strengthen or weaken the received sound due to mechanism of sound waves interferation. A study of Mama [12] has found similar situationon influence of background noises. In this study when a 100 dBA sound source of a motorcycle engine at road was applied, the indoor sound intensity at center of worship room was recorded at level 67.1 dBA, or equal to 32.9 dB of NR (Noise Reduction). As it is known that the value of Noise Reduction (NR) is equal to sound source intensity minus received sound, or $NR=IL_1-IL_2$ as mentioned in the equation 3. In the next step when applying a noise source of 90 dBA, it was recorded indoor sound intensity level at 75.6 dBA or NR equal to 14.4 dB. However byapplying 70 dBAof sound source, the Noise Reduction (NR) can achieve just 8.6 dB, that is mean a sound intensity of 61.4 dBA was recorded inthe center of worship room. This is the lowest indoor sound intensity that was found in the measurement of Sam Ratulangi University Church. For comparison, a study from Mediastika [14]show that opened window of building envelope can only produce NR in the range of 5 to 10 dB. The results of the study of Du (Du *et al*, 2019) also show that NR of building envelope with a large porosity can only range from 8 to 12 dB. Values of NR that were found in this study are not much different from the study of Du [4] and Mediastika [14]. In addition, the sound intensity that was heard in the interior of the church of Sam Ratulangi University was not meet to the standard of indoor noise according to SNI 03-6386-2000 (Indonesia Standar), which should be maximum 35 dB.

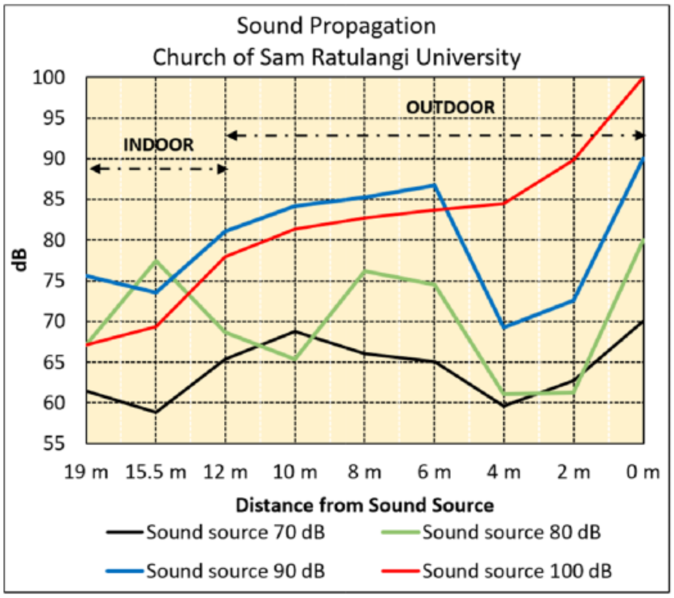

Figure.5. Measurement results of Sam Ratulangi University Church

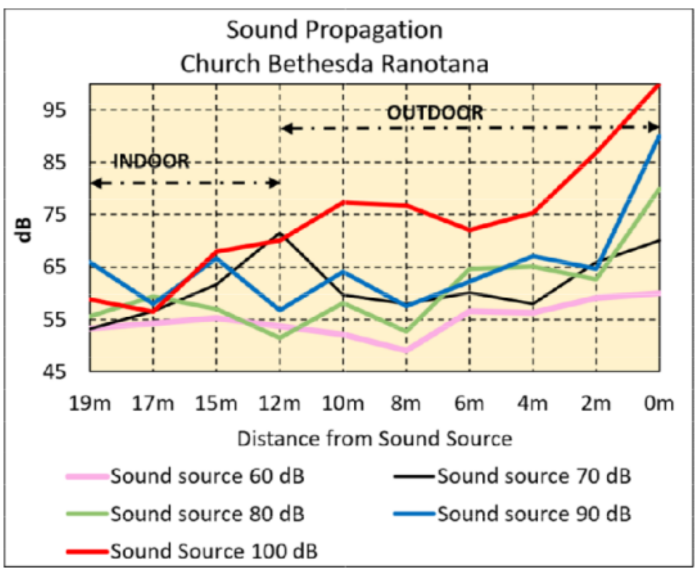

Figure.6. Measurement results of Bethesda Ranotana Church

Similar results and tend of NR were obtained by sound measurements at the Bethesda Ranotana Church (Fig. 6). By applying sound source 100 dBA, it was found indoor sound intensity 58.5 dB, or NR equal 41.5 dB.
At the measuring points at a distance of 4 to10 m there are indications of anomalies, where the sound level increases slightly. This may be due to unanticipated background noises, such as the sound of birds, wind, vehicles, etc. The graph in Figure 6 generally shows that at a distance of 2 to 6 meters from the sound source, the noise intensity level decreases significantly, and after that, decreases with a gentle slope, which is close to the logarithmic graph pattern as stated in the theory of sound propagation.

The graph in the figure 6 also show that the sound intensity level in the room did not meet the maximum noise standard of the church's worship room according to Indonesia Standard (SNI). Indoor sound that was found in this study was categorized too loud. Even by applying a sound source with a lower intensity of 60 dB(A), it was obtained indoor sound intensity 53.2 dBA, or NR just only 6.8 dB. According to Indonesian standards, the maximum noise level in a church room is 35 dB(A).

Comparisonsbetween measurement and calculation were realised. The calculations were conducted by using equations(Eq.1 to Eq.4) from Patel [15] and by using the I_Simpa program. In this calculation, the value of *SRI* (Eq.4) was set at 8 dB that refers to the study by Du [4]. In this step the room was considered in empty situation. Sound absorption impact of body people is therefore neglected in this calculation step. The results of the comparison are shown in the tables 1 and 2.

The level of sound source 100 dB was chosen in thediscussion of the comparison since a loud of 100 dB is considered to represent the sound of horn, where the sound of car horns is generally between 90 to 102 dB[19].

Table.1. Comparison results of sound level (in dB)of Sam Ratulangi Univesity Church

Mode	Point sound reception & distance from source								
	Indoor		Outdoor						
	1	2	3	4	5	6	7	8	9
	19m	15.5m	12m	10m	8m	6m	4m	2m	0m
Manual NR Calculation	70.7	70.7	78.6	80.1	82.1	84.6	88.1	94.1	100
By Software I_Simpa	71.4	73.3	78.5	79.9	81.9	84.4	87.9	94.1	100
By measurement	67.1	69.3	77.9	81.3	82.7	83.7	84.5	89.8	100

Table.2. Comparison results of sound level (in dB) of Bethesda Ranotana Church

Mode	Point sound reception & distance from source									
	Indoor			Outdoor						
	1	2	3	4	5	6	7	8	9	10
	19m	17m	15m	12m	10m	8m	6m	4m	2m	0m
Manual NR Calculation	73.9	73.9	73.9	78.6	80.1	82.1	84.6	88.1	94.1	100
By Software I_Simpa	71.6	74.6	74.9	78	80	82.1	84.6	88.1	94.2	100
By measurement	58.8	56.4	67.9	70.1	77.3	76.8	72.1	75.4	86.9	100

The comparison between the measurement results and the calculation of sound intensity are presented in the Tables 1 and 2 with specifically discuss the sound source of 100 dB. In the Table 1 it is shown that the Church of Sam Ratulangi University, by manual calculation, the sound intensity level reach 70.7 dB in the middle of the worship room. This value is 3.6 dB higher than the measurement results. Based on the simulation using I_Simpa, the sound intensity in the center of the room is 71.4 dB, which means it is 4.3 dB greater than the measurement results. The difference between measurement and calculation results is not more than 7%. By paying attention tothe value of the sound intensity level that is in the middle of the room, it can also be seen that the amount of noise reduction resulting from manual calculations is (100-70.7)dB=29.3dB. Meanwhile, by using the I_Simpa software, it can be seen that the amount of Noise Reduction is (100-71.4)dB=28.6dB. The measurement results show that the Noise Reduction is (100-67.1)dB=32.9 dB. The noise reduction values indicate the total role of the distance factor from the sound source, courtyard landscape, and interior architecture in reducing noise from the road. To find out the single role of interior architecture in reducing the noise, it can be shown by the difference between the noise on the outside wall position, and against the center of the room (Table.3). Based on the results of manual calculations, interior architecture contributes to noise reduction of (78.6-70.7)dB=7.9dB. Meanwhile, based on the measurement results, the contribution of interior architecture to noise reduction is (77.9-67.1)dB=10.8dB. From the results with I_Simpa, it can be seen that the role of interior architecture for noise reduction is (78.5-71.4)dB=7.1dB.

Table.3. Values of Noise Reduction by applying outdoor sound at 100 dB

Methode	Total Noise Reduction From road to Center of room		Noise Reduction due to interior	
	Sam Ratulangi University Church	Bethesda Ranotana Church	Sam Ratulangi University Church	Bethesda Ranotana Church
NR Calculation	29.3	26.1	7.9	4.7
Software I_Simpa	28.6	28.4	7.1	6.4
Measurement	32.9	41.2	10.8	11.3

A similar tendency was also found in the case of the Bethesda Church, where noise reduction was found between 26.1 and 41.2 dB. These values indicate the role of distance to noise sources, landscaping, fence and interior architecture of the Ranotana Bethesda Church on totally noise reduction. The role of interior architecture in noise reduction ranges from 4.3 to 11.7 dB.As comparison, the results of measurements at the Puh Sarang Church in Kediri City, Indonesia, which has openings of 50% at the corresponding wall, are only able to reduce noise by about 11 dB at frequency from 500 to 1000 Hz[16].

The results of the visualization of sound propagation through the simulation using software I_Simpa, show the role of window openings that contribute to the entry of noise into the room (Figures 7 and 8). Figures 7 and 8 also show that in positions outside the building, sound propagation does not experience obstacles as indicated by an even color map, but behind the walls of the building, a color map appears showing that some sound is blocked, and only part can enter. However, the noise that still enters the building, the intensity level is still too loud, for the case where the sound source on the street is 100dB.

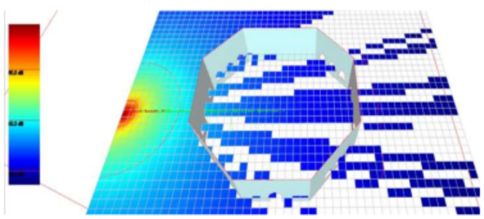

Fig. 7. Pattern of sound propagation in Sam Ratulangi University Church

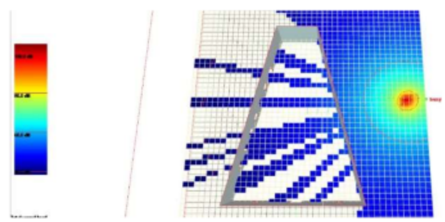

Fig. 8. Pattern of sound propagation in Bethesda Ranotana University Church

3.2. Analysis of a proposed modified interior and wall

The results of measurements, manual calculations, and software simulations, show that the existing designs of the two churches do not produce good acoustic quality in the inner room, and this is at risk of disrupting worship activities inside. Therefore, in the next stage it is necessary to propose a design improvement that can produce adequate noise reduction.

In this step, it is proposed to improve the architectural design of the church building which consists of improvements to the wall system and its interior. The envelop wall is proposed to be a massive soundproof wall with windows and doors tightly closed. It is still possible to have openings only for the need of additional natural lighting, but not for ventilation holes that are always open to the outside, because this will cause the entry of sounds from outside that can disturb worship activities. Noise reduction from a wall system as in equation 4, consists of two parts, namely the role of SRI of the wall adjacent to the outdoor space, and the role of acoustic properties of the interior. In order to achieve a higher SRI, it is necessary to apply a wall system with a certain material and thickness, so that the sound from outside experiences a large sound transmission loss. Meanwhile, to achieve a better acoustic properties in the interior, it can be done by adding acoustic materials to the surface of the walls, floors and ceilings. In addition, soft furniture and the human body are also good as sound absorbers.

The use of window glass may still be applied, with the condition that the construction or type of glass is able to isolate noise significantly. The use of glass at wall is still needed for natural light opening, although it doesn't need to be too wide.

The wall, which is made of 11 cm thick plastered masonry, can reduce sound by 36 dB (at a frequency of 250 Hz), 40 dB (at a frequency of 500 Hz) and 50 dB (at a frequency of 1000 Hz) as mentioned by Szokolay [20]. A similar value of the sound reduction by brickworks or masonry plastered are also shown by Granzotto [7].

The frequency range of the sound is taken between 250 to 1000 Hz, with the consideration that the average traffic sound which includes the vehicle engine and horn is generally in that frequency range [11]. On the wall can be located a window pane to enter natural lighting. The sound insulation due to double glass with a thickness of 6 mm each 10 cm apart, can reach 35 to 50 dB at a frequency of around 250 to 1000 Hz. Meanwhile, single glass with a thickness of 6 mm is only able to reduce sound by about 25 dB at a frequency of 250 to 1000 Hz [11]. In the improvement design proposal, the double glazing is used but with an area of only 10% of the wall. In general the construction of double glazed windows is expensive. Therefore, the application of double glass is not too many.

The amount of sound absorption in the room also plays a big role in reducing noise. In the practice of indoor acoustics, sound absorbing materials are used on the inner wall surface. The use of the type of chair also contributes to the sound absorption rate. In general, soft materials such as carpets and textiles, as well as rubber, have good sound absorption properties. These materials can be applied in the improvement of church design. Information regarding the amount of sound absorption coefficient of each material can be obtained from many sources, including Szokolay [20]. Heavy carpet material has a good sound absorption coefficient of 0.65 which can be used for floors, and can even be attached to the wall surface. While at the ceiling can be used plywood with a sound absorption rate of 0.15. The chairs made of soft materials which are also potential as sound absorption. The acoustic properties of this chair material are able to absorb 0.15 (absorption coefficient) per seat [20].

In the proposal for improvement of the design, a simulation was made, where the walls are made of masonry and attached by heavy carpet at indoor surface. The floor tile is also covered by heavy carpet. The ceiling is made of plywood. The chair is made of soft material. There is a double glazed window on the wall, but only 10% of the area of the related wall. In the room there are 200 chairs made of soft material. This type of material will be applied to the design of the two churches. By applying such a building envelope, the amount of SRI is 40 dB by considering the frequency value 500 Hz of the received sound level.

The results of calculations by using equations 4 and 5 are shown in Tables 4 and 5. The acoustic quality of the design improvement will be able to increase the Noise Reduction value, and therefore can produce an adequate sound level intensity in the room, compared to the initial design.

In the case of the Sam Ratulangi University church, by applying a 100 dB sound source on the street, by design improvements, it can produce a 45.9 dB of sound reduction in the room, and the indoor sound level intensity can be reduced to 28 dB. While by using the initial design, the calculation of the soundintensity level in the room can reach 70.7 dB (Table.1). Meanwhile, the Indonesian standard on noise criteria or sound intensity level in worship rooms is 35 dB maximum.

However, improvements to the interior acoustics of the church has resulted a reverberation time of 0.5 seconds. While the required value is in the range between 1.6 to 2.8 seconds. Design improvements by applying a lot of sound-absorbing materials in the room, on the other hand, causes a lot of reduction in the number of reverberations. However, to produce an appropriate reverberation time in indoor space, it can be done by applying a sound system or electro-acoustic technology [8]. The echo sound can be adjusted on the amplifier device and the placement of the loudspeaker and microphone in the room which can produce an adequate reverberation time. In the next study, electro-acoustic simulations can be carried out to obtain an echo sound in accordance with the function of the church room.

In the case of Bethesda Ranotana Church, by using the same improvement design concept, a greater noise reduction can also be produced. Therefore the maximum sound level value in a room that meets the requirements can be obtained, which is less than 35 dB, which in this case it can be obtained a value of 34.2 dB (Table 5). If the sound source on the street is less than 100 dB, an indoor room sound level of less than 34.2 dB will be obtained. By applying the improvement design, it is shown that the reverberation time at the Bethesda Ranotana church has also been reduced to only 0.65 seconds, while the standard range value of reverberation time for the church room is 1.6 to 2.8 seconds. In this case, the use of the electro-acoustic concept is also possible to increase the value of the reverberation time for the future research.

Table. 4. Results of Acoustical Calculation of a Proposed Design Improvement of Sam Ratulangi University Church. Sound source at road=100 dB

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Surface	Area	unit	a	a x Area = Sabin	Note:
Wall	384	m^2	0.65	249.6	Heavy Carpet
Ceiling	344.5	m^2	0.1	34.4	Plywood
Floor	344.5	m^2	0.65	223.9	Heavy Carpet
Window	38.4	m^2	0.18	6.9	Double Glass
Chair	200	unit	0.15	30.0	Soft Material
Sigma Area			=	1111.3	m^2
Sigma Sabin			=	544.8	Sabin
As			=	139.5	m^2
NR (Indoor)			=	45.9	dB
IL(indoor)			=	28.0	dB
RT (Reverberation Time)			=	0.50	second

Table.5. Table. 4. Results of Acoustical Calculation of a Proposed Design Improvement of Bethesda Ranotana Church

Surface	Area	unit	a	a x Area = Sabin	Note:
Wall	532.35	m^2	0.65	346.0	Heavy Carpet
Ceiling	446.8	m^2	0.1	44.7	Plywood
Floor	446.8	m^2	0.65	290.4	Heavy Carpet
Window	59.15	m^2	0.18	10.6	Double Glass
Chair	200	unit	0.15	30.0	Soft Material
Sigma Area			=	1485.1	m^2
Sigma Sabin			=	721.8	Sabin
As			=	262.0	m^2
NR (Indoor)			=	44.4	dB
IL(indoor)			=	34.2	dB
RT (Reverberation Time)			=	0.65	second

4. Conclusion

From the results and analysis by calculations, measurements and simulations on indoor sound quality ofSam Ratulangi University Church and Bethesda Ranotana Church, it can be concluded as follows:

a) The sound level in the room is categorized not meet the sound level standard based on Indonesia'sbuilding code, where according to the code, the maximum sound level in the room due to outside noise is 35 dB, while the results of calculations, measurements and software simulations show that by application of outdoor noise of 100 dB at distance about 10 m from the building, the sound level in the room can exceed 50 dB,.

b) The level of noise reduction due to existing walls and its interior sound absorption factors, based on the calculation results, is only slightly, or not significant, which only reaches 2 to 3.4 dB. However, based on measurements, it can reach 16.2 dB at the Bethesda Ranotana Church and 7.5 dB at the Sam Ratulangi University Church.

c) The pattern of sound distribution into the room, based on visualization using software, shows the intensity of sound propagation that is also influenced by the role of openings at wall such windows, doors and ventilation holes.

d) By means of design improvement, it willpossible to obtain indoor sound level which is in accordance with the standard. Simulation calculations are carried out by trying to apply various alternative of wall properties and sound absorption materials to the interior wall layers. However, too much sound absorption material can cause a decrease in the reverberation time which is below the standard. Therefore, the role of the electro-acoustic system is needed to increase the reverberation time, through further studies.

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