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Auditorium Model Assessment with Corrected Acoustic Function

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ABSTRACT

The study of acoustic function is growing to be important today. In the conditions of the development of an all-artificial civilization, it turns out that complementary electronic ornaments are still very dependent on the level of success with the form of the structure and composition of the room itself. The problem arises when an adjustment on one side, intended for improvement, actually shifts the ideal coordinates on the other side. For this reason, a comprehensive adjustment and correction idea should emerge as a solution, with acoustic studies as a starting point. This study tries to describe the ideal design based on investigations and observations of the actual condition of the auditorium of the National University and also tries to determine the suitable material for the room. The stages carried out in the research can be adapted to the needs of the research. This step is to get the most comprehensive results with the most effective and efficient steps. Integrated software and trial and error analysis are also part of the research method. It was found that the new design of the National University auditorium has good acoustic insulation with some adjustments that are still possible to get the ideal standardization of the room.

1. Introduction

Acoustics (from the Greek akouein = to hear) is an applied science intended to stimulate the sense of hearing. The 1st-century Roman architect Marcus Pollio had begun to carefully observe the echo and interference (original sound vibrations and reflected vibrations cancelling each other out) of a room. Nevertheless, it was not until 1856 that acoustics began to be developed as a science by Joseph Henry and was finally fully developed by Wallace Sabine in 1900. Both were American physicists. However, unfortunately, our country's trend is generally to ignore acoustic design except in unique rooms such as concert halls, recording studios, or theatre stages. Whereas in any room, for people whose hearing senses are sensitive, being in a room with bad acoustics is torture.

Acoustics is an interdisciplinary science concerned with studying all mechanical waves in gases, liquids, and solids, including vibration, ultrasound, sound, and infrasound. Experts define *acoustics* as the theory of sound waves and their propagation in a medium. A scientist who works in acoustics is an acoustician, while someone who works in acoustic technology can be called an acoustic engineer. We can see the application of acoustics in almost all aspects of modern society, the most obvious being the audio industry.

The study of acoustic function is growing to be important today. In the conditions of the development of an all-artificial civilization, it turns out that complementary electronic ornaments are still very dependent on the level of success with the form of the structure and composition of the room itself. The problem arises when an adjustment on one side, intended for improvement, actually shifts the ideal coordinates on the other side. For this reason, a comprehensive adjustment and correction idea should emerge as a solution, with acoustic studies as a starting point.

In linguistics, room acoustic conditions significantly affect the outcome of a message delivery process. This theory developed in the realm of acoustic phonetics.

The design of the auditorium is not special to fulfil specific functions. The auditorium can be used for speech activities, watching movies, listening to music performances, or other crowd activities. This condition causes differences in sound reflection levels for each auditorium function in calculating the required reverberation time (RT) value. According to the need for a space with a conversation function, it takes RT, which is in the range of 0.85-1.3 seconds, while for the music function, it takes RT calculation whose value lies in the range of 1.3-1.83 seconds (Ribeiro, 2002). The difference is needed. Therefore, the RT value that appears for the room's function has an effect that functions well. An RT that is too short will cause the room to feel dead. On the other hand, a long RT gives a lively atmosphere to the room, but for a room with a conversation function, it will cause a decrease in speech integrity. (Satwiko, 2004, p. 91). The room interior covering material that functions as an absorber or reflector significantly affects the RT value achieved. (Doelle, 1972. p. 63).

The acoustic aspect of the room that determines its suitability with its function in the room's design is often left out. Consideration of the aesthetics of space alone is not enough for its design. Suitable listening conditions are something that supports room user satisfaction. However, the design of a performance building or lecture often does not consider the acoustic parameters that support the room's success to carry out its functions when used as happened in the auditorium of National University. From the results of field measurements obtained, the reverberation time value is 0.75-1.19 seconds. So, it is necessary to remake this auditorium room to meet existing standards.

In this study, the research location is the auditorium which acts as a meeting room at the National University. This study tries to describe the ideal design based on investigations and observations of the actual condition of the auditorium of the National University. This research also tries to determine the suitable material for the room. The audio system's design develops according to the composition and existing standards after the material design meets the standard criteria. The composition in question is how to provide insulation treatment against noise around the room.

New research is worth doing if it touches at least one of these two traits: urgent and interesting (Siregar et al., 2021, p. 51). This research aims to create a room design with a maximum quality standard. This standardization can be seen from an acoustic perspective related to noise criteria, acoustic insulation, reverberation time, and other objective parameters so that the designs are under the standards.

2. Literature Reviews

The auditorium is a place to watch a speech or a particular performance, such as theatre and music. Acoustic design for theatre performances must satisfy every audience in various locations to hear the articulation of speech so that the nuances and dramatic effects displayed can be captured and digested by the audience. In musical performances, the articulation of music and the expression of actors is not the main thing. However, the most important thing is that audiences from various locations must hear and enjoy the music.

Most auditoriums have problems with the background noise level exceeding the required noise criteria, thus affecting the acoustic performance of the auditorium (Legoh, 1993). The criteria commonly used to measure the acoustic quality of the auditorium are subjective and objective parameters. Subjective parameters are more determined by individual perceptions in a speaker assessment by listeners with an index value between 0 to 10. Subjective parameters include intimacy, spaciousness or envelopment, fullness, and overall impressions, usually used for theatre and concert hall acoustics (Legoh, 1993).

Ideally, room acoustics conditioning and design must be handled from a macroscope (from environmental arrangement) to finally pole to a microscope, namely conditioning and interior design and acoustic activity spaces (Sutanto, 2015). The failure of this conditioning and design is the most frequent factor in achieving the ideal orientation of a room.

The stages of conditioning the acoustic environment are as follows.

1. Macro environment, namely the environment around the site in the form of a land or water environment, and a noisy environment or a quiet environment.

2. Medium-macro environment, namely the environment inside the site but outside the building, is a site environment conditioned to support acoustic activity.

3. Medium-macro-microenvironment, namely inside the building, but outside the acoustic room.

4. Microenvironment, namely the environment in the acoustic room.

Conditioning the acoustic environment on the microscope uses the reverberation time calculation using the Sabine formula as a parameter for measuring the acoustic quality of the room (Doelle, 1986). Sabine's formula is the result of dividing the room volume by the total area of the absorption coefficient plus the sound absorption coefficient if the calculation is carried out in the frequency range of 1,000 Hz. The auditorium room, which is already ideal for multipurpose activities, has a reverberation time of 1.2 seconds for the frequency range of 125 – 4,000 Hz (Satwiko, 2004).

As mentioned earlier, the function of an auditorium determines the acoustic design applied to the auditorium. This condition is to achieve acoustic conditions that can be sufficient for activities in the auditorium space. This difference in acoustic design also causes acoustic criteria and tests depending on the auditorium type. However, several criteria are used to design room acoustics, namely the noise level and reverberation time or reverberation time.

The noise in a room can be compared to a closed room with any function. This condition is due to the source of noise levels that can come from within the space itself (internal noise) or from outside the room (external noise) (Acoustical Society of America, 2000). Sources of noise from within the space itself can come from equipment that functions, such as air conditioning and lighting systems. Sources of noise originating from outside the room are very dependent on the position of the space, where this source can come from operating transportation equipment or other spaces where activities are taking place. Although the noise that space can experience regardless of its function is roughly the same, a suggested minimum noise level depends on the activity carried out within the space. 25 dB is the list of minimum noise levels suggested by Leslie Doelle (1993) where the recommended noise criteria for a room in a school environment.

Reverberation time is the most commonly used parameter in room acoustic design. Wallace C. Sabine created this parameter in the 19th century. Factors that affect reverberation time at an average temperature of 22°C are room volume (V), listener capacity, and absorptive or reflective scope (A). Thus, if the building materials have a more significant coefficient and area, the lower the reverberation time. The auditorium reverberation time (RT) parameter varies depending on its use. The interior surface covering material, related to the absorption and reflection coefficients, is very influential in determining the RT of an auditorium (Doelle, 1972). A room with an inner surface absorbing sound energy (very short RT) is called an anechoic chamber, while a room with an inner surface that is sound reflective (a very long RT) is called a reverberation chamber. The reverberation time of an auditorium used as a speech auditorium in a school environment is recommended to be between 1 and 1.5 seconds. The Acoustical Society of America suggests this like. For a music auditorium, the reverberation time is recommended to be between 1.5 to 2 seconds, while for multifunction, it is 0.3 seconds (Mediastika, 2005).

In every room, felt or not, there will always be sound. This variable is the basis for understanding the existence of background noise. *Background noise* can be defined as sound originating from other than the primary sound source or unwanted sound. In a closed room such as an auditorium, background noise is generated by mechanical or electrical equipment in the room. They are such as air conditioning, fans, Etc. Likewise, noise that comes from outside the room, such as traffic noise on the highway, noise in the vehicle parking area, Etc.

Background noise cannot be eliminated but can be reduced or reduced through a series of acoustic treatments against the room. The amount of room background noise can be known through the measurement of the Sound Pressure Level (TTB) in the room in the middle frequency range of the octave band between 63 Hz to 8 kHz, where the measurement results are used to determine room noise criteria by mapping them on the noise criteria curve (Noise). Criteria– NC). The NC value can be calculated from the measured sound pressure level with $NC \cong 1.25(LA - 13)$ (2.1), wherein the above equation LA is the Sound Pressure Level on the average of all measurement points.

3. Research methods

This research took place in several stages. The stages carried out in research can be adapted to research needs. This step is to get the most comprehensive results with the most effective and efficient steps.

The first stage measures the background noise and NC on the research object. After that, it is continued by measuring the room's characteristics, namely the volume of the room and the materials that make up the room, to then be simulated using Google Sketchup. RT calculation and select the material that has been determined according to the standard in the next step. The next step is to find the appropriate Transmission Loss (TL) to get LP2 due to external noise. Which then looks for the appropriate TL value to get LP2 due to noise from within. In this step and before, if it is not following the standard, it is necessary to repeat the steps in material selection. Next is an audio system simulation using Ease 4.3, which looks for acoustic parameters through the system, namely C-50 and C-80. If these steps are not standard, the following activities must repeat the simulation to find a suitable sound. If appropriate, proceed with data analysis and end with the preparation of a recurring report.

This reverberation time data collecting procedure was carried out in the auditorium before being designed using a Sound Level Meter (SLM) connected to a laptop with FFT Analyzer software installed. This measurement is carried out three times at 1 point. This measurement is carried out when the room is empty. Firecrackers are used to generate impulse signals. This firecracker is used because the impulse generated is quite large and capable of producing sound intensity up to 110 dB.

In the end, all the data obtained will be analyzed according to the needs of the research orientation. It also uses the consideration of the principle of benefit, which means that data that does not support the research orientation will not be used as a reference in making research conclusions.

4. Results and Discussions

The stages carried out in research can be adapted to research needs. This is done to get the most comprehensive results with the most effective and efficient steps. Background Noise measurement is carried out at 1 point and is taken for 1 minute when all activities are in the auditorium room. The background noise measured in this case is the sound pressure level generated by the noise from the equipment in the room. Measurements are made by operating all the lights and air conditioners to get conditions close to the room's daily operation.

From the measurement results of the existing background noise, the Noise Criteria is 37 dB. This shows that the existing auditorium room is not following existing standards, where the auditorium room must have an NC of 25 dB. So, we need an excellent acoustic insulation design so that the background noise is per the standard, which has NC 25.

The measurement of the room reverberation time (RT) is determined at 1-point right in the middle of the room, representing the points in the audience area and expressed in RT60. The reverberation time is obtained by measuring the impulse response using an impulse signal in the form of a firecracker eruption. By standard, the allowed reverberation time for an auditorium is 0.3 seconds. In this study, the current reverberation time was 0.82 seconds.

Based on the noise criteria table, it can be seen that for speech purposes, the ideal is NC 25. However, this value can be reduced to NC 35 if the noise is only heard occasionally. However, if noise occurs all the time, NC 25 should be applied.

Seen in the auditorium of the National University, by activating the lighting and air conditioning, the noise criteria are NC 37. This condition shows that the National University's auditorium does not meet the requirements as a discussion place. This condition is the initial determinant of how successful the design of a designed space is. To reduce the noise criteria from 37 dB to 25 dB is to install the optimal acoustic insulation. By knowing the value of the absorption coefficient on each material, the performance of the designed insulation can be measured by calculating the TL.

First, the average reverberation time is calculated for three measurements to analyze and get the room's reverberation time. Based on the research results, the auditorium of the National University has a reverberation time of about 0.82 seconds. It is assumed that the acoustic conditions of the National University auditorium room are not good enough because ideally, an auditorium room has a reverberation time of 0.3-0.6 seconds. The long reverberation time at the auditorium of National University is possible because the reflected field from the room's surface is not enough to absorb the sound. The entire surface of the room does not have a sound suppression system. This causes the sound is not absorbed correctly. As a result, the bouncing sound takes a long time to get the same value as the background noise.

The level of speech intelligibility (Speech Intelligibility, SI) in the room states how clearly the listener can capture the information conveyed by the speaker. The measure of the clarity of speech here is an objective measure, which means the level of clarity of the speech can be measured in the form of physical parameters and expressed quantitatively. The value of the clarity of speech obtained is expressed in Clarity (C-50 and 80).

Based on the results of data analysis, based on the C-50 data, the average value of C-50 is -1.40 or negative. In contrast, the minimum limit for C-50 that can still be tolerated is -2dB, while for C-80, it has an average of 0.21. The two parameters of the level of clarity of speech at the Auditorium of National University are pretty good. This condition is due to the relatively large amount of sound energy utilized compared to the total sound energy and residual sound energy. According to the standard, one of the contributing factors is the room's reverberation time.

In this study, it can be seen that the distribution pattern of speech intelligibility for C-50 is almost evenly distributed throughout the room. As for the C-80, it is also almost evenly distributed throughout the room. If we refer to the standard, it can be good because the value of C-80 and 50 National University auditorium rooms is -2 to 2, so it is pretty good.

The average is obtained by 0.32. The average value of 0.32 for the auditorium of the National University is sufficient to reduce the long reverberation time. It can be seen that the reverberation time of the measurement is quite long, which is 0.82 seconds. To reduce the long reverberation time, what can be done is to use acoustic dampers on the walls and roof of the room. Using the Sabine equation can obtain the average coefficient of the room for the desired reverberation time. So by entering the desired reverberation time value of 0.3 seconds and in the equation, the average coefficient (α) is 0.3016.

With an average of 0.3016, the National University auditorium reverberation time can function as a discussion room. To get an average (α) of 0.3016, that is, by covering the walls and roof with acoustic dampers.

The background noise of the National University auditorium room looks quite large. We can determine this from plotting to the Noise Criteria Curve, which is 40 in the condition that all equipment is activated. This noise can be overcome by using a material with a certain thickness. Thus, noise from outside will not enter inside.

Background noise is always present in every room. Background noise can be caused by equipment in the room or sounds from outside. If it is too large, the background noise generated by the equipment in the room will decrease the quality of the clarity of speech in the room. In a room with high background noise, the conversation will be at a sound pressure level more remarkable than the background noise itself so that the listener can well capture the information conveyed. Talks or conversations can occur well if the room has a noise criterion (NC) between 25-35.

From the results of data analysis, it was found that the auditorium of the National University had a noise criterion of NC 37. So, the auditorium room of the National University did not meet the criteria for a room that had NC 25-35. The high NC value is caused by:

1. Poor dampening system in the building.

2. There is noise due to structure

Once rebuilt, the acoustical dampers on the walls will be optimized, thereby increasing the sound absorption performance of the room. One of the behaviours of sound in an enclosed space is the phenomenon of hum. *Reverberation* is a reflected sound that appears after the direct or original sound. In this case, the room volume factor, the reflected field, and the absorption coefficient from the room's surface significantly affect the sound reflection.

The auditorium used for talks requires optimal time so that the conversation can take place correctly. Reverberation time that is too long will result in unclear conversations because the sound produced by the speaker will be distorted by the sound that was previously issued because of the sound that had not previously lost its energy. On the other hand, if the reverberation time is too short, the room feels "dry" because the sound resonance disappears so quickly.

A reverberation time of 0.82 seconds was also found. This condition is quite long considering its function as a space for conversation and listening. Meanwhile, the recommended reverberation time for the talk room is 0.3-0.6 seconds. This long reverberation time is caused by the lack of sound-absorbing materials with a significant absorption coefficient so that they are not sufficient to absorb the existing sound.

The clarity of speech in the room shows how clearly the listener can catch the information conveyed by the speaker well. The measure of the clarity of speech here is in the form of Clarity (C-50 and 80). In this study, the C-50 value was -1.40 or negative. While the minimum limit for C-50 that can still be tolerated is -2dB, while for C-80, it has an average of 0.24. when compared with existing standards, the results of the existing design are pretty good.

Covering the reflecting surface of the room with acoustical control material with a high absorption coefficient can be an effective and efficient measure to overcome the shortcomings in this segment. This step is a strategy to reduce reflections and increase sound absorption so that the reverberation time of the room can be reduced significantly, which will indirectly cause the residual and total sound energy to be smaller and increase the ratio of energy utilized and in the end, will be able to increase the level of speech intelligibility.

5. Conclusion

A. The new design of the auditorium of National University has good acoustic insulation, as seen from the average LP2 obtained due to external noise of 27 dBA or has an NC noise criterion of 37.

B. The high NC value is caused by the structure's poor soundproofing system and noise.

C. Simulation results using walls in brick, plywood, and fiber configurations with thicknesses of 11 cm, 1 cm, and 0.7 cm, respectively, provide good acoustic insulation. It can be seen from the Lp2 value, which is reduced by 15 dB from Lp1.

D. The reverberation time value generated before the redesigned room had an average value of 0.82 seconds. According to the material used, the value changed to 0.42 seconds after the redesign. These materials are fiber on the walls, alice on the chairs, gypsum on the ceiling, carpet on the floor, and wood on the doors.

E. After being redesigned, the STI value is 0.57%, and %Alcons is 4.28 % for clarity of conversation in the auditorium. Clarity C-80 and C-50 are 0.24 and -1.40, respectively, with the configuration of the speakers according to the standard.

F. Acoustic conditioning in the medium-macro-microenvironment is carried out by providing transitional spaces in the form of circulation spaces between the auditorium and other rooms.

Based on the study's conclusions, it is recommended that the composition and layout of the construction and equipment of the auditorium room be adjusted to the recommended standards. This step is very influential in achieving the expectations of the role and function of the auditorium room. It is highly recommended to conduct a more in-depth study to formulate the most effective and efficient strategy and execution for the adjustment.

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References

[1] Barron, M. (2009). Auditorium Acoustics and Architectural Design. New York: Spon Press.
[2] Doelle, L.L. (1972). Environmental Acoustic. New York: McGraw-Hill Publishing Company.
[3] Egan, M. D. (1988). Architectural Acoustics. New York: Mc-Graw-Hill, Inc.
[4] Everest, F. Alton dan Pohlmann, Ken C. (2009). Master Handbook of Acoustics. New York: McGraw-Hill.
[5] Ilmi, M, (2004). Signal To Noise Ratio Analysis Relating to Speech Intelligibility Criteria in Auditorium Room, Final Project, ITS Physics Engineering Department, Surabaya
[6] Lawrence E. Kinsler, Austin R. Frey, Alan B. Coppens, James V. Sandera, (1982). Fundamental of Acoustic, John Willey and Son Inc, Singapore.
[7] Long, M. (2006). Architectural Acoustics.Burlington: Elsevier Academic Press.
[8] Mediastika, C.E. (2005). Akustika Bangunan Prinsip-Prinsip dan Penerapannya di Indonesia. Jakarta: Erlangga.
[9] Ribeiro, M R. (2002). Room Acoustic Quality of a Multipurpose Hall: A Case Study. Proceedings of the First Conference with International participation, Bucharest. Sabine, W.C. 1993.Design for Good Acoustics.Los Altos, U.S: Collected Papers on Acoustics, Trade Cloth ISBN 0-9321 Peninsula Publishing.
[10] Satwiko, P. (2004). Building Physics 1. Yogyakarta: Andi Offset.
[11] Setio P. Z, (2003), Acoustic Room Analysis From Auditorium By Applying Speech Clarity Measures Based On Acoustic Energy Ratio, Final Project, Engineering Physics Department ITS, Surabaya
[12] Siebein, G. W., Gold, M. A., (2000). Ten Ways to Provide a High-Quality Acoustical Environment in School, J. Acoust. vol. 31. 376-384J. Wang, "Fundamentals of erbium-doped fibre amplifiers arrays (Periodical style—Submitted for publication)," IEEE J. Quantum Electron., registered for publication.
[13] Sabrina, A., Siregar, I., & Sosrohadi, S. (2021). Lingual Dominance and Symbolic Power in the Discourse of Using the PeduliLindungi Application as a Digital Payment Tool. *International Journal of Linguistics Studies*, *1*(2), 52–59. https://doi.org/10.32996/ijls.2021.1.2.8
[14] Siregar, I. & Siregar, R. (2021). The Relevances between Poda Na Lima Philosophy with Islamic Perspective. *Budapest International Research and Critics Institute (BIRCI-Journal): Humanities and Social Sciences*. https://doi.org/10.33258/birci.v4i4.3240
[15] Siregar, I. & Salsabila. (2021). Acts of Illocutionary Speech by Ganjar Pranowo in the "One Hour Closer" Talkshow. *International Journal of Arts and Humanities Studies*, *1*(1), 95–100. https://doi.org/10.32996/ijahs.2021.1.1.14
[16] Siregar, I. & Sabrina, A. (2021). Representation of Religious Values in Gurindam Twelve and Their Relevances with Modern Era. *International Journal of Cultural and Religious Studies*, *1*(1), 50–57. https://doi.org/10.32996/ijcrs.2021.1.1.7
[17] Siregar, I. (2021). Verbal Communication of Schizophrenic Patients Due to Neurotransmitter Distortion. *QALAMUNA: Jurnal Pendidikan, Sosial, Dan Agama*, 13(2), 543-556.
[18] Siregar, I. (2020). *Exploration and Implementation of the Cultural System as a Solution to National and State Problems*. http://repository.unas.ac.id/id/eprint/811
[19] Siregar, I. (2021). Analysis of Betawi Language Interference on the Morphology of Adolescent Speech in Jakarta. *Journal of Humanities and Social Sciences Studies*, 3(8), 54-60. http://doi.org/10.32996/jhsss.2021.3.8.7
[20] Siregar, I. (2020). *Geografi Leksikon Betawi*. Jakarta: LPU Unas
[21] Siregar, I. (2021). Epistemological Challenges Against Sociolinguistics. *International Journal of Linguistics Studies*, 1(2), 37–42. https://doi.org/10.32996/ijls.2021.1.2.6
[22] Siregar, I. (2021). The Existence of Culture in its Relevance to the Dynamics of Globalization: Bahasa Indonesia Case Study. *International Journal of Cultural and Religious Studies*, 1(1), 33–38. Retrieved from https://www.al-kindipublisher.com/index.php/ijcrs/article/view/2285
[23] Siregar, I., Rahmadiyah, F., & Siregar, A. F. Q. (2021). Linguistic Intervention in Making Fiscal and Monetary Policy. *International Journal of Arts and Humanities Studies*, 1(1), 50–56. https://doi.org/10.32996/ijahs.2021.1.1.8
[24] Surakarta, B. K. (2016). Surakarta City in Numbers. Surakarta: CV Nuansa Fajar.
[25] Sutanto, H. (2015). Acoustic Principles in Architecture. Yogyakarta: PT Kanisius.