

# RECYCLED BRICK SOUNDPROOF TEST AS AN ALTERNATIVE SUSTAINABLE MATERIAL

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**Abstract:** Brick debris that makes up the majority of construction waste has not received proper waste disposal in Indonesia. On the other hand, brick debris could be potentially reused as non-structural building materials to reduce its negative impact on the environment. This study aims to test the effectiveness of soundproofing on recycled brick debris. The soundproof test was carried out on brick debris in the form of fine and coarse grains. The simulation box is then used as a support for the brickwork material and then the box is exposed to a sound source with a certain level of noise that is considered disturbing human comfort. Noise level measurements are made in the outside and inside the box. These measurements are tabulated and then analyzed to see the success of the two aggregates in reducing noise. Basically, the brickwork material has succeeded in becoming a recycled building material that can absorb noise, although further research must be carried out to be able to state that this material is truly ready to be used as an alternative building material with good acoustic capabilities.

**Keywords:** construction waste, sustainable construction, sound insulation, brick waste recycling

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## **Backgrounds**

Construction waste is a major contributor to waste production in landfills. In Hong Kong, construction waste accounts for 38% of waste production (Tam & Tam, 2006). Studies conducted in the United States show that construction waste production reaches 569 tonnes (EPA, 2019). In the UK, construction waste production accounts for 60% of total waste generated (DEFRA, 2019). Globally, construction waste contributes to 40% of waste production (Holm, 1998 in Kulatunga, 2006).

Unfortunately, in Indonesia, construction waste has not received sufficient attention. Processing construction waste into recycled material has not become an issue of sustainable construction in Indonesia (Sembiring, 2018). In addition, there is no clear data record regarding the amount of construction waste production in Indonesia.

In fact, sustainable construction has the potential to be developed by utilizing recycled materials. Sustainable practices by recycling building materials can reduce the amount of waste that accumulates in landfills. This will reduce the negative impact of construction activities on the environment.

One of the construction wastes is brick (Firmawan, 2012). Brick waste covers 50% -70% of total construction waste (Cheng, 2016). Without a proper waste treatment, brick waste will accumulate in the soil. It will further damage the absorption of groundwater (Townsend and Kibert, 1998 in Firmawan 2012).

One of the potentials for reusing brick rubble is as sound insulation. This study aims to identify the properties of brick as sound insulation. Brick debris that has lost its structural properties is reused as a non-structural element as a development

of environmentally friendly materials.

## **Problems**

Shelters in Indonesia that are offered by developers and those that are independently established are usually close to noisy sources. The source of the noise is often come from motorized vehicles. Due to cost savings, developers could not afford to provide extra land that can act as sound buffer. Hence, it is important to keep the wall soundproof.

Furthermore, residential owners often carry out renovations to meet the increasing need for space in line with the growing number of family members. These renovation activities often involve dismantling of old buildings which consequently result in the building debris. If the building debris is reused, it could potentially saves up the total construction budget (Sembiring, 2018).

Based on the background that has been mentioned above, the author tries to do a research to link the problems above and then searches for the answer. The author tries to use a brick wall as a wood wall filler and at the same time finds out whether the material is capable of being a noise absorbing material. For this reason, the research team formulated the following questions:

- Is used brick optimal as a sound insulation material?
- Does the size of the brick grains affect the quality of sound insulation?

## **Theories**

One of the disturbances that are present around residential areas is noise disturbance, or noise. With the increasingly

dense urban area and the closer the residential area to the circulation route, noise disturbance cannot be avoided from residential areas. The way residents can do this is to reduce the sound with a variety of known tech-niques, ranging from simple to difficult and possibly expensive.

Mangunwijaya in his book Introduction to Building Physics said that noise can interfere with human physical and mental health. Humans should make efforts to reduce noise in order to get hearing pleasure related to the comfort of living. It is necessary to pay attention to how to apply various acoustic treat-ments in buildings, around buildings, and on noise sources (Mangunwijaya, 1988: 162).



Figure 1. Noise Levels from Different Sources

Figure 1 shows that the comfort-able level of noise for a quiet room is within the range of 20 dB to 40 dB (Ro-drigue, 2020). Outside this pressure range, sound can already be said to in-terfere with human hearing and comfort. Actually, there is another factor to be able to say that a sound disturbs human hearing, that factor is frequency. A sound pressure of 80 dB isn't necessarily more distracting than

a sound pressure of 10dB. Level of loudness is also measured by its frequency. Figure 2 shows that sound level pressure of 80dB with 16 Hz frequency is as loud as sound level pressure of 10dB with 1KHz frequency. Both have level of loudness of 10 phons. This means that sound decibels cannot be used as the only standard in measuring the level of loudness or sound disturbance in the human ear. However, in this study only sound pressure level will be of concern.

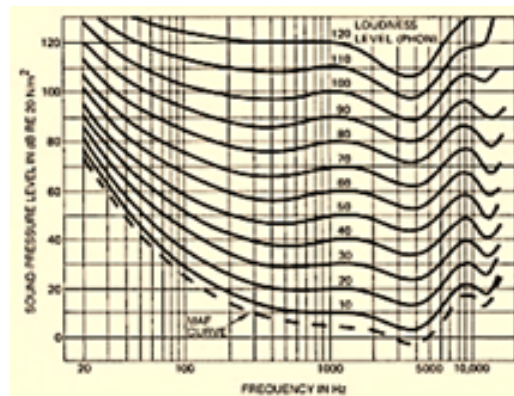


Figure 2. Relationship between Pressure and Frequency (source: Leslie L. Doelle, 1993)

Actually, at the threshold of 20 to 30 phons, voices can still be accept-ed by human hearing in a dwelling. This indicates that the sound with a pressure of 80db in a house can still be tolerated only if the frequency is 20 Hz.

The next thing that should be of concern is how humans can isolate the sound so as not to interfere with hear-ing comfort in the dwelling. There are three countermeasures to reduce sound level: at the sound source, on the path traversed by sound, and in objects or spaces that must be protected against sound interference. The three of them involve limiting resonance, sound absorption, proper construction methods, proper arrangement

of the area around the building, and building plan planning (Mangunwijaya, 1988: 168). This research focuses more on sound suppression techniques or through sound absorption techniques.

Wood is a material that can absorb sound as well as a resonator because of the strong interlocking cavities of wood that can convert sound energy into heat energy. There is no other material that has better acoustic capabilities than wood, which is why wood is often used as a material for making acoustic musical instruments (Mangunwijaya, 1988: 183). This study also used wood as a simulation box to represent the space in a dwelling. However, keep in mind that what is of concern in this research is the brick wall and not the wood itself, although of course the wood material will have a significant influence on the results of future research.

## **Previous Research**

In construction projects, construction waste can arise due to the residual cutting of material (Andiani, 2011). The remaining cut material will become debris which is then transported to the final waste disposal site. The brick debris is one of the remains of the cutting of the material.

Brick rubble waste has received wide attention from various researchers. Ling et al (2013) found that the compressive strength of bricks decreased along with the increasing composition of brick debris in the mixture of materials. Other studies by Jankovic (2002), Gonzalez et al (2017), and Cavalline & Weggel (2013) focus on the reuse of brick as a structural element by testing the performance of recycled bricks as concrete aggregates. This study shows that the optimal brick as an aggregate is at 30% of the total aggregate mixture.

These studies indicate that recycled bricks are not optimal when reused as structural materials. Another alternative is to use brick debris as a non-structural element. However, testing the ability of brick debris as a non-structural element has not been carried out.

The use of brick debris as a sustainable material can be used as a complement to wooden walls. Compared to other wall materials, wood is more sustainable because it can be renewed through good wood processing management. Wood has the lowest carbon emission value compared to other materials (Falk, 2009). The use of wood as a wall material can also minimize the resulting carbon emissions.

## **Methods**

This research uses a conditioned box model to simulate the real situation. Hence, research can be conducted out anywhere. In this study the location chosen was the researcher's residence with the consideration of ease of access and could be done at any time and did not disturb the environment because the test was carried out in the house.

The types of data collected are primary data and secondary data obtained through experiments, observation, recording, and literature study.

Primary data were collected by recording any changes observed in the measuring device placed in the study box. Each data obtained due to changes in sound intensity given to the model is tabulated into three columns of data groups. The column contains data on the original sound intensity, sound intensity in the control box, and sound intensity in the research box.

The tabulated data is then analyzed using sound intensity comfort standards for humans in a living room.

This study tested the acoustic quality of brick debris. Rubble is divided into two types: fine and coarse. Smooth brick debris is brick debris that has been sieved. Meanwhile, rough brick debris is brick debris that does not pass through the sieve.

Rubble was inserted into the hollow multiplex wall. Three variables were tested: The walls in the first box were inserted with fine brick debris, the walls in the second box were inserted with coarse brick rubble, and the walls in the third box were the control variables without being given brick debris.

The three walls are then tested for their acoustic quality with an acoustic sound measuring instrument. Tables of measurement and recording results are then analyzed to obtain final conclusions.

## Discussion

Sound absorption quality is tested in a model box that simulates noise caused by the vehicles sound or other noise that often passes through a residential area. It is impossible for the researcher to carry out the test in real conditions because the subject and research variables can-not be controlled for both time and presence. Because of this condition, it is necessary to create a model or situation that can represent the real conditions to be studied.

For this reason, a room model needs to be made to represent the conditions of the room in real situations. The model is made in the form of a box that has 6 closed sides so that it resembles a room in a house even though the size will be smaller. The size of the box chosen is 60 x 60 x 40 cm (figure 3).



Figure 3. Research box (source: processed by researchers)

The material used to make the box is a wooden board with the consideration that it will make it easier for researchers to modify the research box according to research needs. In addition, because wood is a material that is still often used or chosen in building a dwelling and is still relatively inexpensive, apart from being easily formed in the construction process.



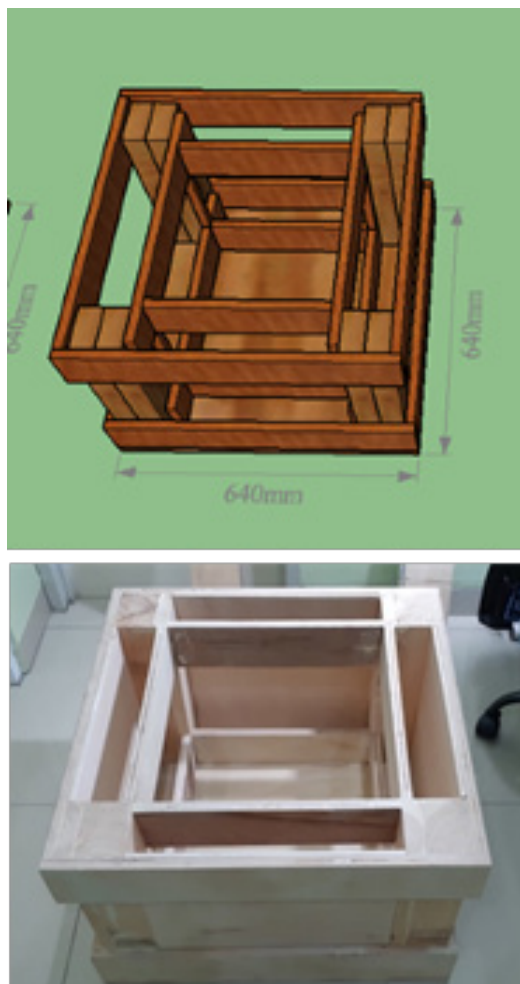


Figure 4. Space on the four sides of the research box  
(source: processed by researchers)

The four sides of the research box are formed with two layers of partitions/dividers which have a space/gap between them (Figure 4). The gap is then filled with material that has been studied for its ability to reduce sound. The dividers on the four sides of the research box can be removed according to the research needs (Figure 5.).



Figure 5. Adjustable divider on the research box  
(source: processed by researchers)

At the top of the box an opening will be given to make it easier for researchers to monitor the contents of the box. the opening will be covered with a glass so that the space in the box is protected from leaking sound. Then a sound intensity measuring device or a decibel meter is placed inside the box to measure the intensity of the sound that enters the simulation box's chamber.

The material tested for its soundproofing ability in this study was brick rubble (rubble). Brick rubble was chosen because this material is commonly found in building demolition and is a potential contributor to accumulated garbage. The background above is one of the reasons why this study tries to explore the potential of brick to be reused as recycled building materials. To limit the scope of the study, this research focuses on the potential of noise reduction by the rubble.

To test the potential of this rubble, two aggregates were used, namely fine and coarse aggregates. The reason for testing using two aggregates is because of the cavity in the aggregate of different magnitudes. The presence of cavity supposedly able to reduce noise level (Mangunwijaya, 1988). The difference in the number of cavities in the aggregate will also be examined for its ability to reduce sound.

To get the aggregate with different conditions, the researcher then smoothed some of the rubble, while some of it was left as it was according to the conditions of building demolition. The grinding process uses a hammer to get fine aggregate.



Figure 6. Rubble refinement process (source: processed by researchers)

To test the noise reduction level, we use a sound intensity measuring device known as a decibel meter. In this study, three decibel meters were used. Prior to study, these three decibel meters were calibrated to make sure that the devices have similar measuring capabilities.

The study required three decibel meters to measure three different conditions. The three conditions are a. noise source conditions, b. conditions in the control box, c. conditions in the research box. Then the measurement results of

these three conditions will be tabulated.

To examine the ability of rubble to reduce noise entering the simulation box, the researchers arranged a research box like the diagram above. The research box is a box in which it will be filled with thick aggregates, while the control box is left empty but has the exact same partition configuration as the research box. The noise source is placed directly in front of the two boxes with equal distances. Inside each box will be placed a sound intensity meter and another will be placed outside the box to be able to directly measure the sound intensity on the outside of the box.



Figure 7. The process of adding fine aggregate (source: processed by researchers)

After the layout is ready, the re-search box is filled with the first brick aggregate, which is the fine aggregate (Figure 7.), on all four sides. While the control box is left as is without any treatment. After the aggregate filling process is complete, the sound intensity meter is placed in the research box and then the research box is closed (Figure 4.8).

In this first condition, the following measurement results are obtained:

- a. Noise source is on level 89 – 98 dB.
- b. The control box is on the level 65 – 70 dB.

c. The research box is on the level 61 – 66 dB.

From the measurement results, it can be seen that the decrease is not too significant, but it is true that there is a decrease when the walls are filled with shallow aggregate compared to when the boxes are not filled (control box).

Then the rubble is removed from the research box and then the box is refilled with coarse aggregate bricks (not through a refining process) (Figure 8.).



Figure 8. Insert coarse aggregate into the research box (source: processed by researchers)

After filling in the boxes, the boxes are rearranged according to the previous layout. Then the measurement again is carried out at the same sound intensity as the previous measurement conditions.

From this second condition, the

following data are obtained:

a. Noise source is on level 89 – 98 dB.

b. The control box is on the level 65 – 70 dB.

c. The research box is on the level 67 – 72 dB.

From the the second condition, it is found that an interesting condition shows that the condition of the control box is relatively lower in sound intensity when compared to the research box which has been filled with coarse aggregate.

From the two measurements under these different conditions, a comparison table is made as follows:

Table 1. Results of Measurement of Sound Intensity Using a Brick Debris on a Wooden Wall (source: processed by researchers)

| No | Condition       | Fine aggregate (dB) | Coarse aggregate (dB) |
|----|-----------------|---------------------|-----------------------|
| 1  | Source of noise | 89 - 98             | 90 – 100              |
| 2  | Control box     | 65 - 70             | 69 – 72               |
| 3  | Research box    | 61 - 66             | 67 - 71               |

From the table above, then a graphical table is created to clarify the picture of the results obtained. The following is a graphic display based on the table above.

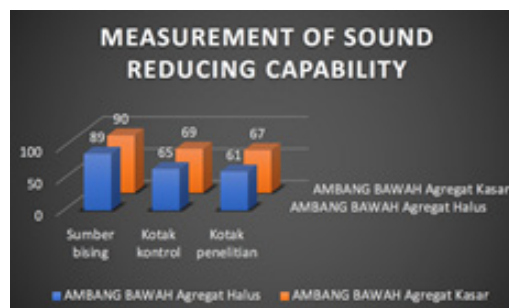


Figure 9. Graph of the Noise Damping Force of Brick Broth Material on Wooden Wall - Lower Threshold (source: processed by researchers)



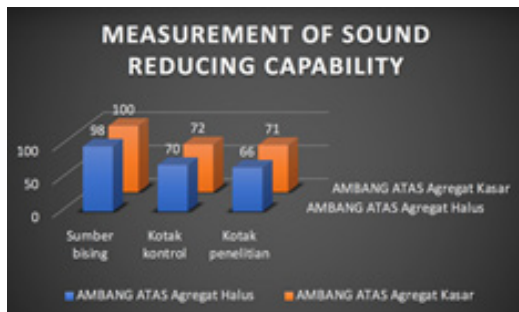


Figure 10. Graph of the Noise Damping Force of Brick Broth Material on Wooden Wall - Upper Threshold (source: processed by researchers)

From the two experiments above which were carried out to determine the ability of bricks to reduce noise, it was found that the use of wooden boxes without adding anything inside was sufficient to reduce noise. The difference between the noise outside and inside the control box is 24 dB at the low threshold and 28 dB at the upper threshold.

With the addition of fine aggregate to the study box, it was found that the damping rate worked even better, although not too significant. The difference measured was 28 dB at the low threshold and 32 dB at the upper threshold. So that the data about the ability of rubble with fine aggregates is obtained at 4 dB at the low threshold and 4 dB at the upper threshold.

In an experiment using coarse aggregate, the following data are obtained. In the control box, there is a difference of 21 dB at the lower threshold and 28 dB at the upper threshold. Then from the box filled with coarse aggregate it is obtained a figure of 23 dB at the lower threshold and 29 dB at the upper threshold. So that from these data, it is obtained that the ability to attenuate a rough aggregate is (23-21) 2dB at the low threshold and (29-28) 1 db at the upper threshold.

From the experiment with this second condition, it was found that the aggregate

bricks that were left coarsely rested had an average damping ability of 1.5 dB. This means that brick aggregate with coarse aggregate conditions has a lower damping power (ability) than brick with fine aggregate which has an average damping ability of 4 dB.

## Conclusion

Research shows that brick debris has sound absorption quality when applied as wall filler. Brick debris is able to reduce noise with a range between 1.5 to 4 dB, although this ability to reduce is not too significant because it is only in the range of 1.5 to 4 dB.

However, it should be noted that the span occurs in brick masonry with unequal aggregates. It appears that fine aggregate has better ability than coarse aggregate. From this difference in aggregates, it can be seen that the air space that is present between the coarse aggregate grains has no effect in increasing the ability to dampen the sound. Fine aggregate grains with a denser level of density actually have a better damping ability and look more constant. The level of damping ability of fine aggregate is seen constant at the lower and upper thresholds.

It should be noted that this study uses a model with wooden walls arranged to create gaps between the walls. The gap between these walls is then filled with brick material. When it is empty, the ability to dampen the wooden plank material in the research box looks very good because it can reduce noise up to 24 dB at the low threshold and 28 dB at the upper threshold. The addition of brick wall insulation material in the gap between the wooden walls increases the wall's ability to reduce noise, although it is not too significant.

This research needs to be continued with research related to the processing of brickwork. In the next stage, it is necessary to examine the ability of the brickwork after receiving special treatment and processing, if it can increase its ability to reduce sound. However, up to this stage, the use of layered wooden walls without the addition of a wall in it is good enough to withstand the noise that can enter the room.

It should also be noted that this study has not applied any other damping principles, such as floating floors or floating ceilings. The application of these principles may further obscure the capabilities of the material under study as happened in this study. So it is necessary to apply a different method so that the raw material shows its ability without being covered by the supporting material (in this case it is wood material).

This study illustrates that the rubble material has the ability to provide sound insulation, even though it is low. This research should be continued to find a way so that rubble can be used as a building material with acoustic capabilities without having to depend on other materials as a support.

Up to this point, this research cannot fully answer that the use of brickwork is an environmentally friendly material that can reduce the negative impact of construction. Still other research needs to be done to be able to state that brickwork is a good recycled material to reduce noise while reducing the negative impact of construction.

It should also be underlined that the wood material in this study states that wood material is still a material that is effective and efficient in reducing sound in residential buildings.

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