The effect of lerak foam and kapok as a silencer on lightweight concrete

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Abstract. Lerak Foam is Foam produced by Lerak fruit mixed with water. This Foam is very suitable as an air cavity enhancer in lightweight concrete. Kapok is a natural material commonly used as pillows, mattresses and stuffed toys. Kapok with fine fibers and easily formed in a concrete mixture is expected to reduce noise. The purpose of this study is to reduce the noise of concrete materials by adding Lerak Foam and Kapok. This research was conducted in the Concrete Laboratory University of Jember, by making a sample of 40 cm x 40 cm x 40 cm concrete box with a thickness variation of 3 cm and 7 cm. This study intend to compare the value of noise reduction and transmission loss from the concrete specimen model with the addition of 100cc Lerak Foam and Kapok with 0%, 1.5%, 2.5%, 3.5% and 5% from the weight of concrete. The different values can be found by giving a noise gauge inside from the concrete box. The level of noise reduction is affected by the thickness of concrete. The level of noise reduction will increase as much as the addition of Kapok Fibers in concrete mixtures.

1. Introduction

One result of the rapid development of infrastructure is noise. The sound from heavy equipment, dump trucks, hammers, has made noises. Loud sounds can impact human life psychologically and biologically. Loud sounds can impact human life psychologically and biologically. The noise can disrupt the hearing system, disrupt the respiratory system, and reduce the concentration. It is necessary to apply sound absorbing devices by using appropriate materials. The development of construction materials that can absorb sound has evolved, but the price of this material is still expensive and not friendly for our environment, such as Styro-Foam [6,13]. Sound absorbing material commonly used is high-density walls such as red bricks, which have a density of 2,000 kg/m3. Therefore, it is required to reduce weight by using lightweight materials, such as lightweight bricks or lightweight concrete [8]. Lightweight concrete has been used since ancient times and it becomes the most interesting part of this research because of the benefits are more economical than conventional concrete, such as lower transport costs, low hydration heat, good heat insulation material, superior in sound absorption, low production costs due to the use of a lightweight and inexpensive aggregates [4]. However, this type of concrete has several disadvantages.
including lower mechanical properties and durability, higher shrinkage and drying creep[7].

Generally, lightweight concrete research used natural material, such as pumice, diatomic, Skoria, volcanic ash, lightweight artificial aggregates such as tile flakes, slate, and ceramic [5,14,17]. Making a lightweight concrete also can be applied in porous concrete, for example, the porous concrete road. According to Nurtanto (2017), Malaysia, the Philippines, and Indonesia, precisely on the island of Java, are producers of cotton in Southeast Asia. The dried cottonwood fruit is a source of fiber source, used as a basis for mattresses, pillows, wall decorations, protective clothing, and stuffed fillings and heat insulation and soundproofing. Dry skin of kapok fruit can be used as a fuel. The seeds that contain oil are used as lubricants and lamp oil, thus can be used as energy raw materials. Lerak or also known as rerek or lamuran is a plant known for its useful uses as traditional detergent. Batik is usually recommended to be washed by Lerak because it is considered as the most suitable washing instrument to maintain the color quality of batik. Lerak seeds contain saponins, a toxic alkaloid, these saponins produce foam and function as a washing instrument, and can be used as a cleaner for various kitchen appliances, floors, even bathing and cleaning [1]. Lerak fruit can produce large amounts of foam expected in a lightweight concrete mixture that can make air cavities [11]. Kapok is the lightweight concrete mix is expected to be able to absorb sound. In this study, the addition of cotton fiber is assumed to increase the ability of lightweight concrete to reduce the noise with the same mechanical properties as conventional concrete. This research was conducted to compare the value of noise reduction and transmission loss from conventional lightweight concrete models with lightweight concrete with the addition of Lerak Foam and Kapok.

2. Experiment investigation

2.1 Material used

Lightweight concrete is planned to have a compressive strength characteristic of 20 MPa. The cement used is portland pozzolan cement (PPC) type 1 with a volume weight of 1.195 gr/cm³ and a specific gravity of 3.02 gr/cm³, using Jember local sand mining with volume weight of 1.57 gr/cm³ and a specific gravity of 2.73 gr/cm³. Pumice as coarse aggregate with a volume weight of 0.54 gr/cm³ and a specific gravity of 0.93 gr/cm³. The Lerak Foam used is 100 cc. Kapok was made in such a way to form a circle with a diameter of 1 cm with a weight of 0%, 1.5%, 2.5%, 3.5% and 5% of the weight of cement.

![Lerak Foam and Kapok](image)

Figure 1. Lerak Foam (a) and Kapok (b)

2.2 Mix Proportions

To investigate the ability to absorb sound in lightweight concrete with the addition of Lerak Foam and cotton, conventional concrete is used as a control mixture. The proportion of the control concrete mixture is with a compressive strength of 20 MPa plan by using pumice as the rough aggregate (BN). The Lerak Foam used is 100 cc/m³ of concrete and uses 0% (B0), 1.5% (B1), 2.5% (B2), 3.5% (B3) and 5% (B4) kapok from the weight of cement. From the Table 1, shows the physical properties of
fine aggregates and coarse aggregates. A mixture of proportions and all decreases in value concrete mix is presented in Table 2.

**Table 1.** The results from the test materials

| No | Test Variables | Fine aggregate (%) | Coarse Aggregate (%) |
|----|----------------|--------------------|---------------------|
| 1  | Absorption     | 1.59               | 1.49                |
| 2  | Water Content  | 1.61               | 0.33                |
| 3  | Density        | 2.67               | 2.54                |

**Table 2.** Details of the concrete mixes (per m$^3$).

| Mix Code | Cement (Kg) | Water (Kg) | W/C | Sand (Kg) | Pumice (Kg) | Lerak Foam (cc) | Kapok (Kg) |
|----------|-------------|------------|-----|-----------|-------------|-----------------|------------|
| BN       | 544         | 201        | 0.37| 575       | 54.5        | -               | -          |
| B0       | 544         | 201        | 0.37| 575       | 54.5        | 100             | -          |
| B1       | 544         | 201        | 0.37| 575       | 54.4        | 100             | 8.16       |
| B2       | 544         | 201        | 0.37| 575       | 54.5        | 100             | 13.6       |
| B3       | 544         | 201        | 0.37| 575       | 54.5        | 100             | 19.04      |
| B4       | 544         | 201        | 0.37| 575       | 54.5        | 100             | 27.2       |

2.3 Test Method
Concrete specimens were cast in a steel cylinder with a height of 300 mm and a diameter of 150 mm to determine the compressive strength. The size of hollow-shaped square specimens is 40 cm x 40 cm with the variation of concrete thickness between 3 cm and 7 cm to determine sound absorption. The concrete compressive strength test and density at 28 days that carried in this study based on SNI [15,16]. Sound suppression test with a sound meter based on ASTM [3]. At least, three test specimens were served to obtain an average compressive strength and sound absorption.

3. Test results and discussion

3.1. Density
Table 3 and Picture 2 present the relationship between the level of addition of Lerak Foam and Kapok with density. Test results prove that the addition of Lerak Foam and Kapok is decreased the concrete density. Test results prove that the addition of Lerak Foam and Kapok is decreased the concrete density. This occurs because of the specific gravity from kapok is lower than sand and pumice. Concrete control density normal (BN mixture) 1881 kg/m$^3$. In this range, concrete is considered as lightweight concrete [19]. The addition of 100cc Lerak Foam can reduce the concrete density of about 0.4%.

The addition of Lerak Foam and Kapok with 1.5% cement, 2.5%, 3.5% and 5% can reduce the density of about 1%, 1.9%, 3.4%, and 4.4%. All of the concretes that have dry density of less than 2000 kg/m$^3$ can be considered as lightweight concrete [2]. In the same mixture, the thickness specimen with the smallest density is 3 cm. This is because the concrete constituent material has been partially replaced with Lerak Foam and cotton. The volume with 3 cm thick is smaller than the 7 cm thick, with the volume of Lerak Foam and kapok mixed, the volume of concrete (pasat, aggregate) composition is more often replaced at 3 cm volume. This causes the density of 3 cm thick concrete with the addition of Lerak Foam and kapok lighter.
Table 3. The test results of density

| Mix Code | Average of Density (Kg/m3) |
|----------|---------------------------|
|          | 3 cm | 7 cm |
| BN       | 1.881 | 1.886 |
| B0       | 1.872 | 1.877 |
| B1       | 1.859 | 1.869 |
| B2       | 1.843 | 1.851 |
| B3       | 1.815 | 1.823 |
| B4       | 1.789 | 1.810 |

Figure 2. Concrete Density with different thickness

3.2 Compressive Strength

The compressive strength of all concrete mixes at 28 days is shown in BN containing a rough aggregate of pumice without the addition of Lerak Foam and kapok that considered as a control concrete. Table 4 and Picture 3, shows the relationship between the level of addition of Lerak Foam and kapok with compressive strength. Concrete compressive strength, BN, shows the compressive strength of 28 days is 21.76 MPa. The compressive strength decreased due to the addition of Lerak Foam and Kapok. The mixture of B0, B1, B2, B3, and B4 showed 2.6%, 5.1%, 7.3%, 8.96%, and 10.4%, reveals the lower compressive strength compared to control mix (BN).

The decline of the concrete compressive strength is mostly caused by weak bonds between aggregates, kapok, and cement matrix. Also, cotton has a significantly lower density which also generates lower compressive strength than concrete. Lo et al stated that the strength of lightweight concrete is dependent on the strength of the aggregates that used, cement paste, and the bonding interface between aggregate and cement paste. The decline of the concrete compressive strength is also caused by an increase of W / C. W / C increases due to the addition of Lerak Foam where the
basic ingredients are from the water. The addition of Lerak Foam with 100cc provides a decrease in compressive strength within 2.6%.

The previous study reveals that the decrease of concrete compressive strength is generally due to the bond damage between the cement glue and aggregate [9]. The weak bond between aggregate and cement mortar is mainly due to the addition of Lerak Foam and cottonwood. High strength lightweight concrete usually has compressive strength in the range of 34-69 MPa with dry air density less than 2000 kg/m³ [20].

| Mix Code | Average Compressive Strength (MPa) |
|----------|-----------------------------------|
| BN       | 21.76                             |
| B0       | 21.19                             |
| B1       | 20.64                             |
| B2       | 20.18                             |
| B3       | 19.81                             |
| B4       | 19.505                            |

**Table 4.** Results of concrete compressive strength test at 28 days

![Figure 3. Concrete Compressive Strength](image)

3.2. Sound Absorption
Because of the limitations of equipment, space and test objects, in this study, absolute values cannot be generated, but the differences sound levels at each frequency are represented by Noise Reduction (NR) and transmission loss (TL) on the decibels (dB) scale. Decibels (dB) are used to measure sound intensity or loudness. The stronger the sound, the higher dB level is increased. Decreasing the unwanted sound levels with one of several ways of acoustic treatments is known as a noise reduction. Transmission loss (TL) generally illustrates the accumulation of reduced energy intensity in the form of waves when the waves propagate out from a source or spread through certain areas or certain types of structures.

Sound transmission class (STC) is a numerical rating of the wall, floor/ceiling capability assembly or other building elements such as a door or window to minimize channel transmission. The higher the STC class, the more voice it has blocked or reduced by building elements[10].
Table 5. STC Ranting’s

| Sound Transmission Class (STC) | Speech Audibility * | Noise Control Rating |
|-------------------------------|---------------------|---------------------|
| 15 to 25                      | Normal speech easily understood. | Poor |
| 25 to 35                      | Loud speech easily understood. Normal speech 50% understood. | Marginal |
| 35 to 45                      | Loud speech 50% understood. Normal speech is heard, but not understood | Good |
| 45 to 55                      | Loud speech faintly heard, but not understood. Normal speech is usually inaudible. | Very Good |
| 55 and up                     | Loud speech usually inaudible | Excellent |

*Given a typical background noise level of 30 dB on the “listening” side

The measurements were executed by testing the model of the test object in a closed room in the Structure Laboratory, Jember University. In every test gap, the specimen is closed by plasticine to avoid the entry of sound from outside through the small gaps from the test object. The hollow specimen is 40x40x40 cm within 3 cm and 7 cm thickness. ASTM E 1050 90, the test object was given a sound source to measure the difference in sound inside and outside the test object model. The sound source is captured by 2 microphones, which are placed inside the test specimen and outside the test specimen. The microphone inside the test specimen is placed 10 cm from the sound source. While the microphone outside the test specimen is placed 60 cm from the test specimen, the sound level inside and outside the test specimen is measured in decibels (dB) using a sound meter.

Figure 4. Lay Out
The amount of sound source used is 57 dB, 69 dB, and 80 dB. To calculate the amount of transmission loss, use the following formula below:

\[
NR = SPL_1 - SPL_2
\]

\[
A = aL
\]

\[
TL = NR + 10 \log S/A
\]

Annotation:
- **NR** = Noise Reduction (dB).
- **SPL₁** = SPL sound sources (dB).
- **SPL₂** = SPL sound receiver (dB).
- **TL** = Transmission Loss (dB).
- **S** = Partition field area (m²).
- **A** = Absorption level from receiving room (m²).
- **a** = Absorption coefficient of material in receiving room
- **L** = Field area on receiving room (m²).

### Table 6. Average noise reduction on specimens of 3 cm thickness

| Mix Code | Noise Reduction (dB) and Transmission Loss (dB) | Sound Sources (dB) | 57 | 69 | 80 |
|----------|-----------------------------------------------|--------------------|-----|----|----|
|          |                                               |                    |     |    |    |
| BN       |                                               | NR | TL | NR | TL | NR | TL |
| 12,33    | 23,39                                         | 12,67 | 23,55 | 12,75 | 23,72 |
| B0       |                                               | 13,67 | 24,64 | 13,75 | 24,72 |
| B1       |                                               | 15,58 | 26,55 | 15,33 | 26,30 |
| B2       |                                               | 17,92 | 28,89 | 17,50 | 28,47 |
| B3       |                                               | 19,67 | 30,64 | 19,83 | 30,80 |
| B4       |                                               | 21,58 | 32,55 | 21,75 | 32,72 |

### Table 7. Average noise reduction on specimens of 7 cm thickness

| Mix Code | Noise Reduction (dB) and Transmission Loss (dB) | Sound Sources (dB) | 57 | 69 | 80 |
|----------|-----------------------------------------------|--------------------|-----|----|----|
|          |                                               |                    |     |    |    |
| BN       |                                               | NR | TL | NR | TL | NR | TL |
| 14,83    | 25,80                                         | 14,92 | 25,89 | 14,50 | 25,80 |
| B0       |                                               | 18,25 | 29,22 | 17,67 | 28,64 |
| B1       |                                               | 19,50 | 30,47 | 19,58 | 30,55 |
| B2       |                                               | 20,67 | 31,64 | 20,75 | 31,72 |
| B3       |                                               | 21,25 | 32,22 | 21,75 | 32,72 |
| B4       |                                               | 22,42 | 33,39 | 22,67 | 33,64 |
Table 6 and Table 7 present the results of NR and also TL on three sound sources of 57 dB, 69 dB and 80 dB. The average values of NR and TL in three sources provide almost the same value in the same lightweight concrete mixture. For the lowest NR and TL values in conventional concrete mix is BN. For the highest NR and TL values in the concrete mixture is B4.

Picture 5 and Picture 6, shows the Noise Reduction value and Transmission Loss value in each concrete mixture. The mix code B0 increases the value of Noise Reduction with the addition of Lerak Foam only. The value of Transmission Loss of 8.85%, 4.72% in the thickness of the specimen 3 cm and 21.11%, 11.61% in the thickness of the specimen 7 cm, with the conventional concrete (BN) as a guideline. Increasing the Kapok's addition also makes the value of Noise Reduction and Transmission Loss increased. This is because of the increasing Kapok's addition to the mixture the value of concrete density decreases[8].

![Figure 5. Average Noise Reduction and Transmission Loss test specimens 3 cm thick](image1)

![Figure 6. Average Noise Reduction and Transmission Loss test specimens 7 cm thick](image2)

![Figure 7. Average Noise Reduction](image3)

![Figure 8. Average Transmission Loss](image4)

Picture 7 and Picture 8 show the effect of specimen thickness with a thickness of 7 cm have better noise reduction and transmission loss values than specimens with a thickness of 3 cm. According to NAIMA Building Insulation Committee (2010), in the B0 mix code, the addition of Lerak Foam has a
significant difference in noise reduction and transmission loss within 4.17 DB. Even though the value of the density decreases, with the addition of cotton fiber the more differences in noise reduction and transmission loss decrease[10].

4. Conclusions
In this study, the lightweight concrete using pumice stone as coarse aggregate with the addition of Lerak Foam and Kapok to examine the possibility of producing soundproof lightweight concrete. The study analyzes the effectiveness of this substitution on density, mechanical properties, and noise reduction and transmission loss of concrete. Based on the test results, then the following conclusions can be drawn:

a. The addition of 100ccs of Lerak Foam and kapok 1.5%, 2.5%, 3.5% and 5% by weight of cement can decrease the density of concrete.

b. Concrete with Lerak Foam shows a lower compressive strength and keep decreases simultaneously with the addition of kapok.

c. Contribution of 100 ccss of Lerak Foam and Kapok up to 5% significantly increases the value of noise reduction and transmission loss in the concrete mixture. This proves that Lerak Foam and Kapok can improve sound absorption performance on lightweight concrete.

d. Insulation thickness has a more significant effect on noise reduction and transmission loss than density.

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References
[1] Ardita, Ferdi. Natural Soap. edition 6. Percik Junior.
[2] Aslam, Muhammad, Payam Shafigh, Mohammad Alizadeh Nomeli, and Mohd Zamin Jumaat. 2017. “Manufacturing of High-Strength Lightweight Aggregate Concrete Using Blended Coarse Lightweight Aggregates.” Journal of Building Engineering 13(July): 53–62.
[3] ASTM E1050 - 12. Standard Test Method for Impedance and Absorption of Acoustical Materials Using a Tube, Two Microphones and a Digital Frequency Analysis System. Annual Book of ASTM Standards.
[4] Bayuaji, Ridho. 2011. “Literature Study and Prospect of Porus Concrete Research as Structural Materials and Building Materials.” m: 1–10.
[5] Green. S. 2014. Pumices Aggregates for Structural Lightweight and Internally Cured Concretes. New Zealand: Department of Civil and Environmental Engineering University of Auckland.
[6] Irwan, Yusri. 2013. “Manufacture and Test of Acoustic Characteristics of Coconut Fiber Composite Board,”
[7] J. Newman, P. Owens 2003 Properties of Lightweight Concrete, Advanced Concrete Technology Set. Butterworth-Heinemann, Oxford.
[8] Kristanto, Luciana, H Sugiharto, R O Wibowo, F Harijono 2013 Conventional Brick Walls and Lightweight Brick Walls, 98–105.
[9] M.A. Mannan, H.B. Basri, M.F.M. Zain, M.N. Islam. 2002. “Effect of Curing Conditions on the Properties of OPS-Concrete.” Building and Environment 37(11): 1167–1171.

[10] NAIMA Building Insulation Committee. 2010. “Sound Control For Commercial And Residential Buildings.http://www.eaglerocksupply.com/application/files/4514/4890/6046/Sound_Control. pdf.

[11] Nugroho, Ananto. 2017. “Effect of Rice Husk Ash on the Mechanical Properties of Lightweight Foam Concrete.” Journal of Civil and Engineering 24(2): 139–44.

[12] Nurtanto, Dwi. 2017. “Contribution of Polycarbonate Flexural Strength to Porous Concrete Plates.” Journal of Civil and Environmental Engineering. 1(4): 1–6.

[13] Putra A. 2015. “Characteristics of Lightweight Concrete with StyroFoam Fillers.

[14] Raka, I Gusti Putu, Tavio, and Dionisius Tripriyono. 2010. “Lightweight Aggregate Concrete with Pumice Stone Substitution as Rough Aggregate Substitution.” National Conference on Civil Engineering (4): 173–80.

[15] SNI 1974. 2011. “Indonesian National Standard Test Method for Concrete Compressive Strength with Cylinder Test Objects of the National Standardization.”

[16] SNI 3402. 2008. “Method for Testing the Weight of Structural Lightweight Concrete.”

[17] Suseno, Hendro. 2013. “The Effect of Skoria Rocks from Mount Kelud Blitar as Rough Aggregates in Structural Lightweight Concrete.” Journal of Civil and Engineering 7(2): 149–56.

[18] T.Y. Lo, W. Tang, H. Cui. 2007. “The Effects of Aggregate Properties on Lightweight Concrete.” Building and Environment 42(8): 3025–29.

[19] Tjokrodimulyo, K. 2007. Concrete Technology. Yogyakarta: KMTS Engineering Faculty, Universitas Gajah Mada.

[20] Yew, Ming Kun, Hilmi Bin Mahmud, Bee Chin Ang, and Ming Chian Yew. 2014. “Effects of Oil Palm Shell Coarse Aggregate Species on High Strength Lightweight Concrete.” 2014.