

The Acoustical Performances of Oyster Shell Waste Based Green Concrete Materials

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Abstract— Research on green materials are continuously carried out by researchers, starting with research on middle-low income housing near the airport suffered by airport noise [1]. The orientation of housing facing the runway will have the biggest sound levels [2,3]. Efforts to control noise at middle-low housing annoyed by the noise will be more effective if housing uses a material that can absorb the sound. Therefore, this research is a part of a whole mapping research on housings noise control solution as a material which needs to be layered by another absorber material. Oyster shells in this research have function as cement substitution and provide aesthetic value on concrete materials. Types of shells observed in this research are: green mussels (*Perna viridis* Linn), blood clams (*Anadara granosa* Linn) and scallops (*Placuna placenta* Linn). All three shells were selected as samples in this study because it has a beautiful shell colors as well as having an acoustic performances.

Keywords-component; green material; oyster shell waste; acoustic performances

I. INTRODUCTION

World construction contributed to CO₂ emissions significantly. To minimize damage to the environment caused by CO₂ emissions, then the concept of green building and green architecture should be applied. The green movement is not only intended to protect natural resources, but also aims to reduce CO₂ emissions and to save energy. One effort that can be conducted is to create a green material that aims at reducing cement and replacing it with other materials. In previous research, a part of cement was substituted by baggase ash. [4,5]. This research aims to create building materials made of oyster shells waste. Oyster Shells are pounded coarse and fine. Coarse scouring substitutes coarse aggregate while fine scouring substitute partially cement. The substitution is aimed to reduce CO₂ emission [6]. Moreover, by using a fine powder shells, then the resulting mortar will look more beautiful than baggase ash material.

This research focus on green materials made from waste of shells. The content of oyster shells is dominated by CaO (Calcium Oxide) and Carbon. At least the elements of Silica results in material cannot be used as an element of the structure, but the content of CaO shall be such a good adhesive in mortar of white cement. The use of shells is replacing the white cement, so that the shells can reduce CO₂ emissions in the construction world [6].

In contrast to previous research, the novelty of this research is the application of shell waste on composite material of concrete which is capable in giving aesthetics and artistic finishing and to be low cost material for low cost housing because it is a waste material.

II. GREEN CONCRETE MATERIAL

A. Previous Research

Previous research found out that polymer and styrofoam waste could be recycled to be polymer mortar and styro-mortar [4,5]. In the study, styro-mortar is lighter than normal concrete mortar. Because of difficulties to be destroyed by the environment, so the polymer and styrofoam waste should be recycled as other useful material such as building material. The polymer waste is classified as a plastic waste [7]. The benefits of polymer mortar are lightened the weight of construction, reduce plastic waste and decrease the building budget due to construction load become lighter. The compressive strength of polymer mortar is 133.33– 166.00 kg/cm², while it has 0.35– 0.80 in absorption coefficient and 52 dB in Sound Transmission Loss [5]. Another previous research observed the benefits of oyster shell waste to be green mortars in building material [8].

B. Research on Material made of Oyster Shell Waste

Indonesia is marine country and rich of sea resources, such as oyster and fish. Oyster and fish become culinary consumption by coastal societies in Indonesia. As it is the second longest coastline in the world after

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Canada, Indonesia become the largest producer of marine resources in the world. In the previous oyster shell research, it was found out that the oyster shell mortar has compressive strength of 160.00– 220.90 kg/ cm²[8].

This research will focus on the acoustical characteristics of oyster shell waste mortar that consist of three type of oyster shell, green mussels (*Perna viridis Linn*), blood clams (*Anadara granosa Linn*) and scallops (*Placuna placenta Linn*).

III. OYSTER SHELL AS RECYCLED CONCRETE AGGREGATE

Research conducted by A.S. Mufti et.al [9] found that the addition of the composition of the shells as coarse aggregate ranging from 17%, 31%, 44% and 55% make compressive strength of concrete were reduced as much as 35.32%. This causes that the green concrete with shells as coarse aggregate cannot be used as an element of the structure in building.

Subsequent research is experimental research of manufacture of shells ash as an eco-cement. In this study a proportion of waste and shell ash has a compositions of 49.1 49.1%:% is the best composition that approximates the properties of portland cement. However, in this ecemen, it has not formed compounds of Ca₃SiO₅ yet which is the main compounds of portland cement [10].

In contrast to the both of studies, this research uses shells as either fine or coarse aggregate. And the compressive strength test result described that the quality of the resulting concrete is Q-200, it means that the compressive strength of material is approximately 200 kg/cm² This research will focus on the acoustic characteristics of the oyster shell mortar which will compare three materials made of: green mussels (*Perna viridis L*), blood clams (*Anadara granosa L*), dan scallops (*Placuna placenta L*).

A. Green Mussels (*Perna Viridis Linn*)

Green mussels is very popular as culinary consumption of coastal society. The content of the element on the green mussels shells have been observed at an Integrated Laboratory, University of Diponegoro.

The contents of green mussels shell are: Carbon 55.36%; Na₂O (natrium oxide) 1.28%, MgO (magnesium oxide) 1.32% and CaO (calcium oxide) 42.04%. Based on the content of the element on the green shells where the element of lime (CaO) is high enough, then the green shells can be used as composite materials [8].



Fig 1. (a) Green mussels (*Perna Viridis Linn*); (b) coarse scouring of green mussels

B. Blood Mussel (*Anadara Granosa Linn*)

Blood clams are classified in the phylum of mollusca [11], class: *Paelecypoda*, family: *arcidae*. Like *Anadara granosa Linn*, *Perna viridis Linn* and *Placuna placenta Linn* are very popular by the community. The contents of the element on the green mussels shells have been observed at the Integrated Laboratory, University of Diponegoro.

The contents of blood clams are: carbon 27.19%; Na₂O (natrium oxide) 0.68%; MgO (magnesium oxide) 1.92%, Al₂O₃ (alumunium oxide) 0.81%, SiO₂ (silica oxide) 2.03% and CaO (calcium oxide) 67.16%. The content of Calcium Oxide and Silica that is high enough then the shells of blood can be used as an aggregate in concrete materials substitution or commonly called Recycled Concrete Aggregate (RCA).

Here are the visualization of blood clams:



Fig 2. (a) Blood clams (*Anadara granosa Linn*); (b) coarse scouring of blood clams

C. Scallops (*Placuna placenta Linn*)

The last one is scallop shell. This kind of scallop is very delicious, therefore this shellfish is a favorite culinary for community in coastal region. Here is the appearance of scallops:



Fig. 3. (a) Scallops (*Placuna Placenta Linn*); (b) coarse scouring of scallops

Based on the content of the element on the *Placuna placenta* Linn, then this type of shells can be used as concrete composite materials. The contents are: carbon 32.73%; Al₂O₃ 14.13%; CaO 34.68%, CuO 9.22%, ZnO 5.08% and ZrO₂ 3.03% and MoO₂ as much as 1,13%.

IV. METHODS

Acoustic characteristics in this study consists of absorption coefficient (α) and Sound Transmission Loss (STL).

A. Sound Transmission Loss (STL)

The Sound Transmission Loss test is quite different with the absorption coefficient test. The Sound Transmission Loss (STL) Test used impedance tube equipped with 4 microphones that have sensitivity to high frequency sound. Sound Transmission Loss/STL of a partition is defined as the ratio of logarithmic between the transmitted sound powers (W_t) and the sound power of partition material which comes to the surface (W_i) [12]. In general it can be formulated as:

$$TL = 10 \log \frac{W_t}{W_i} \tag{1}$$

$$TL = 10 \log \frac{1}{r} \tag{2}$$

Whereas r is the sound transmission coefficient of such material, i.e. the ratio between the transmitted sound power through partition of material against the coming sound. Based on the ASTM E 413-2004, measurement of Sound Transmission Loss in impedance tubes is carried out using the frequency range of 125 Hz up to 4000 Hz with 1/3 octave filter [13].

B. Absorption Coefficients (α)

The absorption coefficient of material can be accurately calculated in the impedance tube. The sound absorption coefficient (α_0) is calculated by measuring the sound pressure that fall on the surface material and reflected by it. The absorption coefficient test refers to the standard of JIS A 1405 1963 [14]. These coefficients

can be calculated using the equation as follows [15]:

$$\alpha_0 = \frac{4}{n + \left(\frac{1}{n}\right) + 2} \tag{3}$$

Whereas α_0 is sound absorption coefficient (dB) and n is standing wave ratio.

V. RESULTS AND DISCUSSION

Further, samples were tested with the new performance parameters of Sound Transmission Loss (STL) and the absorption coefficient (α) that was carried out in the laboratory of acoustics. Results of data tabulation are computerized and then analyzed using SPSS so that the resulting output is in the form of graphs, tables, descriptive analysis and the test of significance with its ranking.

A. Sound Transmission Loss (STL)

Sound Transmission Loss (STL) is the loss of sound energy is in the process of transmission of sound through a kind of material [16]. Testing of STL aims to find out the ability of a material to reduce noise that is transmitted to the outdoors.

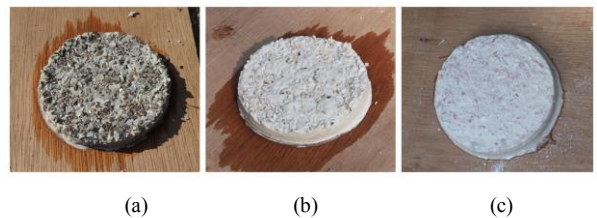


Fig. 4. Sample of materials tested in acoustic laboratory (a) green mussels, (b). Scallops, (c). Blood clams [8]

Either for absorption coefficient or Sound Transmission Loss, the tests were done at a frequency of 500 Hz to 1000 Hz. Dimensions of samples tested has a diameter of 10 cm and 1.5 cm in thickness (see fig. 4). The result of Transmission Loss is described in table and graph below:

TABLE 1. DESCRIPTIVE STATISTIC OF SOUND TRANSMISSION LOSS

Sample	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min.	Max.
					Lower Bound	Upper Bound		
Anadara granosa	251	7.2953	1.05968	.06689	7.1636	7.4270	5.34	9.34
Verna viridis	251	7.2834	.91462	.05773	7.1697	7.3971	5.41	8.92
Placuna placenta	251	6.3931	1.06973	.06752	6.2602	6.5261	4.32	8.41
Total	753	6.9906	1.10027	.04010	6.9119	7.0693	4.32	9.34

From the Data of table 1 as descriptive statistics of Sound Transmission Loss (STL), it can be known [8]:

- The lowest STL of *Anadara*'s material is 5.34 in 500 Hz and the highest is 9.34 on frequency of 950 Hz.
- The lowest STL of *Perna viridis*' material is 5.41 in 500 Hz and the highest is 8.92 on frequency of 914 Hz.
- The lowest STL of *Placuna placenta*'s material is 4.32 in 502 Hz and the highest is 8.41 on frequency of 960 Hz.

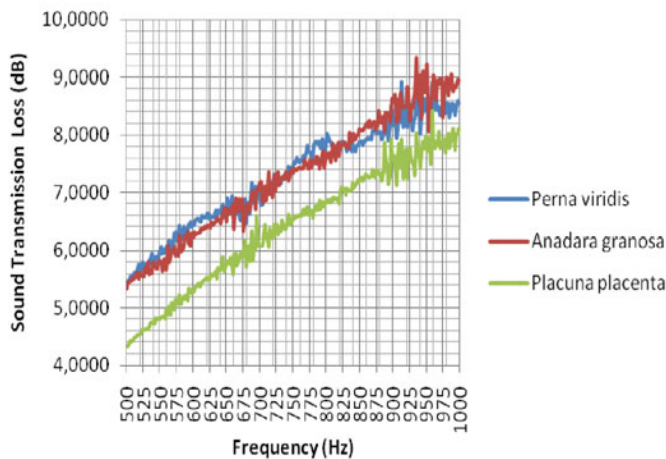


Fig. 5. Graph of Sound Transmission Loss (STL)

From the Fig 5, it can be seen that the STL value of the green material made of *Anadara granosa*, *Perna*

viridis and *Placuna placenta* tend to increase in line with increasing of frequency. The STL graph curve of materials made of *Anadara granosa*, *Perna viridis* and *Placuna placenta* may still increase at frequencies above 1000 Hz.

B. Absorption Coefficients (α)

The absorption coefficient is a measure of the rate of decrease in intensity of sound as it passes through a given substance; the fraction of incident radiant energy absorbed per unit mass or thickness of an absorber; "absorptance equals 1 minus transmittance".

Here are the test data processed consist of the amount of data, average, standard of deviation, standard of error, confidence intervals, minimum and maximum values

From the data in tables and descriptive statistics, it can be known :

- The lowest absorption coefficient of *Anadara granosa* is 0.03039 on a frequency of 520 Hz and the highest is 0.05835 on a frequency of 950 Hz.
- The lowest absorption coefficient of *Perna viridis* is 0.03698 on frequency of 518 Hz and the highest is 0.07350 on 1000 Hz.
- The lowest absorption coefficient of *Placuna placenta* is 0.03707 on frequency of 524 Hz and the highest is 0.06080 on 990 Hz.

TABLE 2. DESCRIPTIVE STATISTICS OF ABSORPTION COEFFICIENT

Sample	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min.	Max.
					Lower Bound	Upper Bound		
Anadara granosa	251	.03900	.008397	.000530	.03796	.04004	.03039	.05835
Perna viridis	251	.04734	.009188	.000580	.04620	.04848	.03698	.07350
Placuna placenta	251	.04422	.005984	.000378	.04348	.04497	.03707	.06080
Total	753	.04352	.008676	.000316	.04290	.04414	.03039	.07350

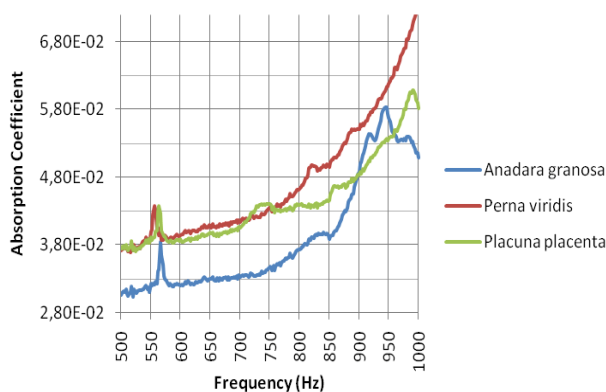


Fig. 6. The absorption Coefficient Graph

From the graph above, seen that the value of the absorption coefficient of a material made from green sample *Anadara*, *Perna viridis* and *Placuna placenta* tend to increase in line with increasing frequency. The graph is still increasing chances of mussels on frequencies above 1000 Hz. Whereas the graph of ussels and shellfish scallop showed a peak and decline in the frequency of 980 Hz.

On the frequency of 554-566 Hz, the graph shows fluctuations in the value of the absorption coefficient for all samples. Fluctuation can occur due to the frequency of the tube impedance used have a different sensitivity than other frequencies.

From the all chart and table analysis, acoustic performance of a sample of material made of shell waste can be summarized in the following table.

TABLE 3. ACOUSTICS PPERFORMANCE OF MATERIALS

Sample of Shell	Absorption Coefficient		Sound Transmission Loss	
	Value*	Rank	Value**	Rank
<i>Anadara granosa</i>	0.04	2	7.3	1
<i>Perna viridis</i>	0.05	1	7.3	1
<i>Placuna placenta</i>	0.04	2	6.4	2
Total	0.04		7.0	

The table of acoustic performance notes that material made of *Perna viridis* shell is the best than other materials. From the aesthetics, color and shape of *Perna viridis* shell is also more attractive than other materials.

VI. CONCLUSIONS

Acoustic performance of green material made from shells are measured with the parameters [8]

- Sound Transmission Loss (STL) as to the power of the media to inhibit noise, measured in dB, different for each frequency.
- The absorption coefficient (α) that efisistensi sound absorption material on a specific frequency.

The higher the value, the higher the ability of absorbency and mute the sound of the material [8].

From analysis and references, it can be found that sample of material having 1 cm in thickness made of a mixture of waste shells and white cement have the ability of absorbency and mute the sound similar to a thin carpet glued on top of the concrete. Waste shells can be used as coarse and fine aggregates on materials such as terrazzo, ceramics and bricks as well as other interior materials.

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AUTHORS' PROFILE



Dr. Erni Setyowati has become a Member of GSTF (Global Science and Technology Forum), Singapore since March 2013. Erni finished her study of Architectural undergraduate degree at University of Diponegoro, Indonesia in 1990. Then in the same University, she finished her study for master degree in 2000 and doctoral degree in 2011. The major field of study which she concerns is Building Science and Technology.

She works at Architecture Department, Engineering Faculty, University of Diponegoro, Indonesia. She is a lecturer and has become a Chief of Building Technology Laboratory since 2011. The previous publications which she has written consisting “Sustainable Master Plan Design in Residential Area Near the Airport”, presented and published in International Conference Proceeding on the 1st ACE 2013, Singapore and “Housing Orientation and Transportation Noise in Residential Area Near the Airport”, published in National Journal of Dinamika, Civil Engineering, University of Muhammadiyah Surakarta, Vol.10, No:3-September 2010, a National Journal Accredited by High Education Directorat General, BAN DIKTI: 110/DIKTI/Kep/2009. She also wrote the educational book in march 2013: “Thermal and Acoustics”, UNDIP Press Publisher. She has conducted research on Nano-material recently.

Dr. E. Setyowati has become memberships of AMER (Association of Malaysian on Environmental Behaviour Researcher) since 2013, Indonesian Architect Association (IAI) since 2005. She conducted research on Nano material with her students and gained the best five for Eco materials catagory on National Research Competition in 2013.



Dr. B. Gagoek Hardiman was awarded the title of professor by Diponegoro University in 2013. His started to study at Bachelor of Architecture, Diponegoro University in 1975. Then, he got his Ph.D in Architecture and City Planning from Stuttgart University, Germany in 1992.

His academic career began in 1983 as a Lecturer in Architecture Department, Engineering Faculty, Diponegoro University, Indonesia. In 1993-1997 he was the Secretary of the Department. Then in 1995-2000 he led the Master Program of Architecture Engineering having specialization in Tropical Architecture. Currently, he leads Head of Doctor Program of Architecture and Urban Area in Diponegoro University, Indonesia.

His research's topic is Tropical Architecture with several publications on the Journal of Applied Mechanics and Material as well as on the Journal of Engineering and Science.

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