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GREEN CONCRETE MADE OF OYSTER SHELL WASTE TO SUPPORT GREEN BUILDING MATERIAL

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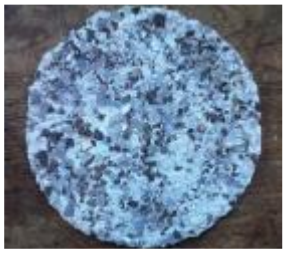
Graphical abstract



Abstract

Oyster shells in this research have function as both cement and fine aggregate substitution as well as 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*). This paper compares performances of concrete materials made of three oyster shells on density, compressive strength and acoustical aspects consisting Sound Transmission Loss (STL) and Absorption Coefficient (a). Green material made of Anadara granosa Linn shell has the greatest compressive strength with the value of 200 kg/cm^2. The acoustical tests show that the three materials have a range of STL between 6.3931 and 7.953 dB, while the greatest absorption coefficient is material made of Perna viridis shell with value of 0,05.

Keywords: Oyster Shell, waste based materials, compressive strength, STL

1.0 INTRODUCTION

This research aims to create building materials made of oyster shells waste. The species of oysters which are observed in this research are: green mussels (*Perna viridis. Linn*), blood clams (*Anadara granosa Linn*) and scallops (*Placuna placenta Linn*). The Oyster Shell was grinded rough and fine. Coarse scouring substitutes rough aggregate while fine scouring substitute partially cement and sand. The substitution is aimed to reduce CO_2 emission [1, 2]. Moreover, by using a fine powder of shells, then the resulting mortar will look more beautiful than sugar cane baggase ash material as observed in the previous research [1, 3, 4, 5].

Novelty of this research is that the wearing of the shells mortar is not only makes beautiful visually, but it can also reduce noise due to the cavity formed out of the rough shells aggregate. Because it is made from waste, the material is expected to be a low-cost alternative material suitable for the construction of low cost housing.

2.0 LITERATURE REVIEW

The shoreline along Indonesia is 81,000 km, the longest shoreline after Canada. With a long shoreline, then Indonesia recorded seafood valued at US $ 1.2 trillion per year [6]. Scallop is a type of *mollusk* that favored by coastal communities although clams particularly vulnerable to contaminants hazardous substances. Types of shells are commonly found in the coastal town of culinary business are: Green mussels (*Perna viridis Linn*), Blood clams (*Anadara granosa Linn*) and scallops (*Placuna placenta Linn*).

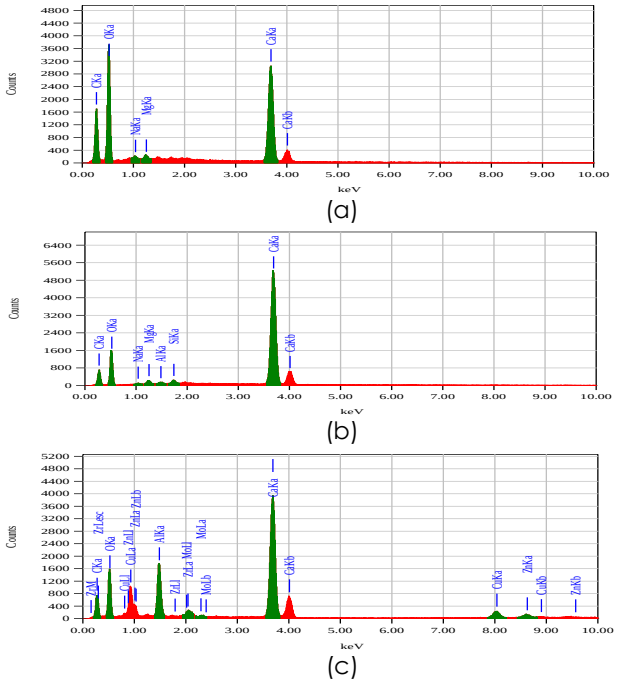


Figure 1 The Scanning Electron Microscope of (a) green mussels (b) blood clams (c) scallops

Refer to results of Scanning Electron Microscope (SEM) Test conducted in Integrated Laboratory, University of *Diponegoro*, the content of green mussels shells are: *Carbon* 55.36%; Na_2O (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 mortar composite materials (see Figure 1a). The content of blood mussels are: *Carbon* (C) 27.19%; Na_2O (*Natrium oxide*) 0.68%; MgO (*Magnesium Oxide*) 1.92%, Al_2O_3 (*Alumunium oxide*) 0.81%, SiO_2 (*Silica oxide*) 2.03% and CaO (*Calcium oxide*) 67.16% (see Fiigure 1b). The content of *Calcium Oxide* and *Silica* is enough then the blood mussels can be used as an aggregate in concrete materials substitution or commonly called Recycled Concrete Aggregate (RCA). Moreover, based on the content of the element on the *Placuna placenta Linn* (scallops), then this type of shells can be as concrete composite materials. The contents are: *Carbon* (C) 32.73%; Al_2O_3 (*Alumunium Oxide*) 14.13%; CaO (*Calcium oxide*) 34.8%, CuO (*Copper oxide*) 9.22%, ZnO (Zinc oxide) 5.08% and ZrO2 (*Zirconium dioxide*) 3.03% and MoO_3 (*Molybdenum trioxide*) as much as 1.13%. Here are visual appearances of flakes of shells (see. Figure 1c). Refer to ASTM C 618, then none of the three oyster shell that actually meets the requirements of the standard and regulation as concrete mortar [7]. However, from an existing *Calcium oxide* (CaO) substance, then the oyster shell of *Anadara granosa* species have such substances more than others.

3.0 METHODOLOGY

Mix design method used in this research is a method of DOE-Mix design aims to determine the composition of the comparison of the material, i.e. the comparison of aggregate, coarse aggregate, fine aggregate as well as cement. In this research in the form of coarse gravel aggregate in the construction of the concrete is replaced with rough shells collision. In addition testing carried out in some vulnerable age concrete. For testing compressive strength test objects to be created a cube 5x5x5 cm [8]. The number of cubes is presented in Table 1.

Table 1 The number of objects in the cube of samples for each Test variation of shells

	Type of shells	7 days age	14 days age	21 days age	Note
Tipe I	Green mussels	3 units	3 units	3 units	*Coarse aggregate and fine aggregate of mortar*
Tipe II	Blood clams	3 units	3 units	3 units	
Tipe III	Scallop shells	3 units	3 units	3 units	

To find out the quality of the blend with aggregate shells then it will do several tests as follows [8, 9].

1. **Density**
   To determine the level of gravity on a composite with a mixture of cement and shells, it is used:
   $$D = \frac{A}{V} \quad (1)$$
   where D is density, A is surface area in cm^2 and V is volume in m^3

2. **Compressive Strength**
   With variations in aggregate green shells, scallop shells and shellfish of blood mixed with the expected to produce robust optimal press
   $$\sigma = \frac{P}{A} \quad (2)$$
   with σ is compressive strength in kg/cm^2, P is load in kg and A is the surface area on square centimeter cm^2.

3. **Absorption Coefficient (a) and Sound Transmission Loss (STL)**

   The test are conducted with the impedance tube device, frequency filter with 1/3 octave would be included then recorded into a computer soft ware (PC) so that the result will be a computerized tabulation [9]. The visual test of STL and the absorption Coefficient (a) on sample material of oyster shell waste is similar

with the test in previous research, see Figure 2 [10].

(a) (b)

Figure 2 Acoustic Test: STL and Absorption Coefficient Test (a) The Impedance Tube [5, 10]

4.0 RESULTS AND DISCUSSION

The data collected from laboratory will be analyzed and discussed.

4.1 Compressive Strength

To ensure that the waste shell can be used as component of concrete material, then the only indicator is conducting compressive strength tests of concrete mortar with the addition of the shell powder as fine aggregate. From the results of compressive strength test with a variety of shells, so it can be summarized as follows:

Table 2 Compressive Strength Test of Oyster Shell Mortar

No	Type of Shell	Age of mortar (days)	Compressive strength (kg/cm^2)	Qualification of mortar
1	Green mussel (*Perna viridis Linn*)	7	26.5	Q-60
		7	35.2	
		14	36.3	
		14	41.1	
		21	61.6	
2	Blood clams (*Anadara granosa Linn*)	7	224.2	**Q-200**
		7	194.8	
		14	243.1	
		14	227.8	
		21	214.6	
3	Scallops (*Placuna placenta Linn*)	7	139.2	Q-175
		7	150.5	
		14	153.0	
		14	160.6	
		21	178.5	

The result in Table 2 shows that mortar made of Anadara granosa shell has the highest compressive strength of the three mortars. The average compressive strength of Anadara granosa shell mortar is 220 kg/cm^2 or 22.09 Mpa which is better than polymer mortar on 133.33 kg/cm^2 and foam mortar on 60.24 kg/cm^2 in previous research [1, 3, 4, 5]. So, this material can be used as structural element material in a single floor building.

Another advantage of the oyster shell mortar is the reduction of the use of cement in the construction industry because it contains sufficient *Calcium oxide* (CaO). Moreover, by using oyster shell mortar then the construction's budget can be saved due to building oyster shell mortar is a waste material. Oyster shell mortar can be used as building materials, such as: terazzo, wall and ceramics. For an example, mix design of terazzo might have a composition materials, white cement: water: shell powder: coarse shell as 2.00: 1.00: 3.00 : 0.75 (see Figure 3a-c).

(a) (b) (c)

Figure 3 Composite of Concrete mortar (a) Green mussels; (b) Scallops mortar; (c). Blood clamps

This research is definitely different with previous research that uses polymer waste and ash, baggase [3, 11, 12]. Although baggase ash on previous research contains elements that is qualified to ASTM C 618, however baggase ash mortar with polymer has compressive strength for only 166 kg/cm^2[3]. Research conducted by Valerie, S. and Assia, D.T., found out that water and fragmentation resistance were found out by the use of polymer aggregate in concrete material [11, 13]. In this study, the compressive strength of *Anadara granosa* shell mortar even reached up to 243.1 kg/cm^2 (see Table 2 above). This is because the content of CaO (Calcium Oxide) of the mortar which is quite high on value of 67.16% (see Figure 3b). In addition, the Carbon element on shell mortar would weaken compressive strength. The lower the Carbon element on a shell mortar, the higher the compressive strength of it. As seen on Figure 3a-c, that the content of the Carbon in *Perna viridis* shell is 55.36%; *Anadara granosas* shell is 27.19% and *Placuna placenta* shells is 32.73%. So, the *Anadara granosa* shell mortar has highest compressive strength of three.

4.2 Absorption Coefficient and Sound Transmission Loss (STL)

Research was started from the manufacture of samples of the material in the form of a plate cylinder with 10 cm in diameter and 1.5 cm in thickness. The mixture of material is coarse aggregate of shells as well as fine aggregate and white cement as adhesives. Further, samples were tested with the new performance parameters of Sound Transmission Loss (STL) and the absorption coefficient (a) that was carried out in the laboratory of acoustics. Results of laboratory test data 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. Sound absorption coefficient which can be calculated is the absorption coefficient of normal sound. The

sound absorption coefficient (a_0) is calculated by measuring aound pressure that come on a surface of material and reflected by it. A good absorber must have an absorption coefficient at least 0,2 [14]. The coefficient can be calculated with equation as below [15]:

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

With a_0 is sound absorption coefficient and n is standing wave ratio. Where standing wave ratio (n) is measured by substituting resistance with attenuation, determining the ratio of the standing waves from the difference of sound pressure (L) db using equation as follows [15]:

$$n = 10^{\left(\frac{L}{20}\right)} \quad (4)$$

Whereas *n* is a standing wave ratio and *L* is the difference of sound pressure. In the process of the absorption coefficient test (a), the acoustics laboratory used impedance tube which is equipped by a unit of microphone to transmit sound frequencies in the range of low to high. Meanwhile, Sound Transmission Loss (STL) is the loss of sound energy in the process of transmission of sound through the a kind of material [16]. The Sound Transmission Loss test aims to find out the ability of a material to reduce noise that is transmitted to the outdoors. 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.

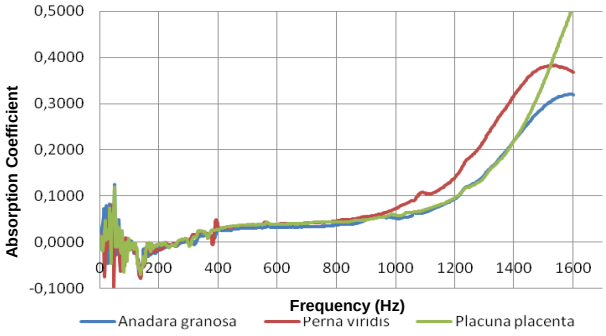


Figure 4 The Absorption Coefficient Graph of Shell Mortar

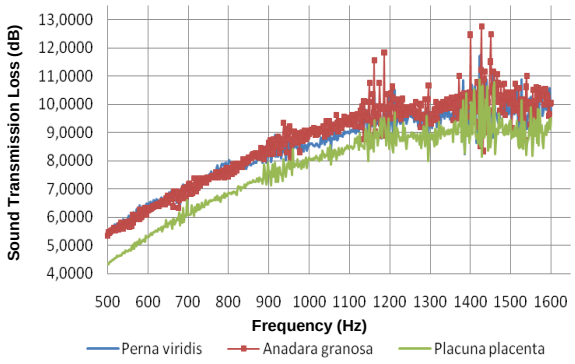


Figure 5 The Sound Transmission Loss of Shell Mortar

From the graph above, seen that the value of the absorption coefficient of a material made from green sample *Anadara granosa Linn, Perna viridis Linn* and *Placuna placenta Linn* are 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 Mussels 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. (see Figure 4). From the graph (Figure 5), it can be seen that the STL value of the green material made of *Anadara granosa, Perna viridis* and *Placuna placenta* are 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 at above 1000 Hz.

Table 3 Acoustics Performance of Shell Materials

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

*) rounded to 2 decimal places behind the comma
**) rounded to 1 decimal

Table 3 shows that *Perna viridis* shell mortar has the best absorption coefficient than others, while *Anadara granosa* and *Perna viridis* shell mortars have higher Sound Transmission Loss than does *Placuna placenta* shell mortar. Either in absorption coefficient test or Sound Transmission Loss test, the three shell mortar tends to have value in average similar.

5.0 CONCLUSION

Waste shells can be used as rough and fine aggregates on materials, such as terazzo, ceramics and bricks in addition can be used also as interior materials such as wallpaper, flower pots, tables and so on. Acoustic performance of these materials needs to be retested because of the huge of absorption coefficient and Sound Transmission Loss will be different on different material thicknesses. The more the thickness, the more the ability of material to absorb the sound. From analysis and references [17], 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.

From Table 2, Figure 4, Figure 5 and Table 3, it is found out that the strongest mortar on compressive strength is *Anadara granosa* shell mortar, while the weaknest one is *Perna viridis* shell mortar. But comparing to the previous research, the compressive strength of *Perna viridis* shell mortar is the same as that of foam mortar [1, 4, 5]. On the other hand, the compressive strength of Anadara granosa shell mortar has exceeded the polymer mortars with nano technology in previous research [3]. As found out in those research that the *nano* technology of sugar cane baggase ash (SCBA) in polymer mortar can increase compressive strength up to 24.50% from 133.33 kg/cm^2 to 166.00 kg/cm^2 [3].

Refer to the ASTM C 33-03, that all shell mortar cannot be classified as lightweight mortars, because the density is more than 1,900 kg/cm^3 [18]. Due to the Figure 3 (a, b, c) and Table 2, that the less the carbon contained in the shells, the higher the compressive strength is. Related to the ASTM C 618, even though the blood mussels shell contains no Fe_2O_3 (*Iron oxide*) less than sugarcane baggase ash mortar, but the substitution of the shell in a part of fine aggregate make it is stronger on compressive strength than polymer-concrete mortar is [3]. On the acoustical test, it is found out that the three oyster shell mortars tend to be not used as absorber material because their absorption coefficient and Sound Transmission Loss is low significantly if they are compared to the acoustical specification of polymer mortar and foam mortar in previous research [1, 3, 4, 5].

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