# ANALYSIS OF PHYSICAL STRENGTH AND POROSITY LEVELS OF STONEWARE CLAY WITH A MIXTURE OF ORGANIC WASTE AS CERAMIC BODIES

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## ABSTRACT

The dumping of unused organic waste from various sectors has had a negative impact on the environment and will also affect human health if it is not treated properly. However, waste such as seashells should not be considered as garbage simply because it has some interesting features to be used as research material. This study was conducted to analyze the physical strength and porosity rate of stoneware clay that has been mixed with organic waste to produce ceramic body. These experiments are conducted in a practical studio and apply physical test based on standard experiments. This study also discusses the potential of organic wastes such as seashells to be applied in clay bodies to produce ceramics. The researcher will conduct experiment on the sample to see the rate of porosity and strength after bisque firing 900°C and 1000°C. The results found that a mixture of seashell powder by 10 per cent was able to improve the physical properties after firing at a temperature of 1000°C. The FC 3 sample had reached the highest strength on the strength test. Therefore, it is hoped that this study can be a guide for ceramic makers to produce clay formulations with a mixture of seashell powder that has the potential to increase the physical strength of ceramics while applying sustainability elements to protect the environment through the concept of waste recycling.

**Keywords:** Ceramic, stoneware, clay, porosity, seashell, organic waste.

## INTRODUCTION

The word ceramic is the origin of the word ceramic '*Keramos*' which uses clay that is formed and fired at a specific temperature for producing a product (Rice, 2015). The word also uses a similar meaning to the type of pottery, besides the term 'ceramic' is more everything related to clay-based materials. In the production of ceramic products, clay media is the main material used, and various types are used which have been categorized such as pottery, stoneware, kaolin, and porcelain. This type of clay is specially classified in its properties and physicality as well as the special characteristics found in each type of clay.

In general, clay minerals have been formed naturally through the process of decomposition of igneous rocks consisting of granite rocks formed through the deposition of liquid from the inside of the earth's crust (W. Ryan, 1978). In addition, the formation of this clay is also strongly influenced by its characteristics and character and even has several categories. Clay that has moved from its parent location is known as primary clay. One of the primary clay categories is kaolin or also known as China clay and this type of soil is a pure type of clay, while the secondary clay is a clay that has moved from its original place. This transfer event usually occurs when carried by currents and rainwater until it settles in the area where the current is carried (Hendrik Norsker, 1990).

According to Wahyu Gatot Budiyanto et al. (2008) clay is the main medium in the manufacturing process of ceramic products that has been used almost all over the world since time immemorial. However, this clay also has its own type and character according to the surrounding area and geography. Clay also has the property that it is easily formed or plastic and will become hard when dried and burned then named as pottery or (ceramic). There are several types of clay that are categorized as ready-to-use clay, namely earthenware clay and stoneware clay. Both types of clay can be used directly to produce products while the porcelain type must go through a process of mixing materials consisting of ballclay and bentonite. The purpose of this material mixture is to add an element of plasticity in the clay so that it is easily formed (Glenn C. Nelson, 1960).

Randy Miller (2020) explained that organic waste is a material or waste derived from plants and animals that can be '*biodegraded*' that is (decomposed naturally) for a certain period. However, during this '*biodegradation*' process, it has indirectly released methane gas, which is a large amount of greenhouse gas that traps heat on the surface of the earth's atmosphere and contributes to climate change factors. In the meantime, this organic waste also contains antibiotics, chemicals and pathogens that will settle into the soil and enter the water source when it decomposes naturally. This will indirectly affect the quality of the environment and will also have adverse implications on human health.

This study was conducted to analyze the physical strength and porosity rate of stoneware clay that has been mixed with organic waste to produce ceramic body. These experiments are conducted in a practical studio and apply physical test based on experiments standard. This study also discusses the potential of organic wastes such as seashells to be applied in clay bodies to produce ceramics. The researcher will conduct experiment on the sample to see the rate of porosity and strength after bisque firing 900°C and 1000°C.

## LITERATURE REVIEW

According to 'Hazardous Waste Experts' (2014), organic waste or waste categorized as '*biodegradable*' is generally waste generated from nature derived from plants as well as animals. Most organic waste is categorized as a non-hazardous material or waste, but it can also cause various disadvantages if disposed of in an improper manner when decomposed and mixed with other materials in landfills. This is because organic waste is also able to emit harmful greenhouse gases as much as 20 times compared to carbon dioxide which in turn will cause many other problems and implications.

However, organic waste should not be considered as a source of environmental pollution that must be eliminated by disposing of it in landfills or burned using incinerators, as this will lead to other pollution problems. Instead, this organic waste must be seen as something valuable and can be converted and processed into a product that can bring benefits as well as profit (Iyganki V. Muralikrishna & Vali Manickam, 2017).

Seashells are a type of '*exoskeleton*' (strong and hard protectors) formed by animals in the category of '*invertebrates*' that live in the sea. It can also often be found on beaches around the world. Animals that have shells for this protection are called "*mollusks*". *Mollusks* use salts and chemicals found in the ocean to form shells as protection from their predators. Among the marine life that has these shells are oysters, clams, snails, and there are also some specific species of squid. In addition, seashells also consist of the element calcium carbonate and have 2 other layers made of '*conchiolin*' and calcite (Jomard, A, 2019).

In addition, there is a study involving a mixture of shell waste used as a ceramic composite to produce a binding mechanism for 3-Dimensional Printing (Binder-Jet 3D) by combining a mixture of seashell powder with plaster. In the study, shell powder combined with plaster proved to be suitable to be produced for 3D printing using the Binder-Jet printing tool. Moreover, the content limit of the shell powder mixture in the appropriate ratio is as much as 20% and this will not affect the mechanical strength rate of the body (Singamneni S, Bahera MP, Le Guen M. & Zeidler H., 2018).

## METHODOLOGY

These experiments are conducted in a practical studio and uses a mixed method by applying the observation method throughout the experiment conducted in a ceramic studio. Observation's method in this study is used to examine character change as well as the nature and physical reactions that occur in the samples tested. Meanwhile, quantitative data is data obtained from observation methods made using formulas based on experimental standards. In addition, this study also uses experimental standards to obtain more accurate data and meet the specifications of physical experiments to produce ceramic body formulas in studio practice.

To produce a ceramic that is strong and has good strength, a pressure strength test must be done to evaluate the rate of strength that can be accommodated by a ceramic produced. Therefore, experimental methods were used in this study. The standards used in this study: India standard (IS: 3495 (Part-2) -1992, RA 2011) to test the level of porosity, 3 Point Flexure Test using: (ISO 14704: 2008) 3rd Edition and Compressive Strength Test using: American Society for Testing and Materials (ASTM C1424). This research also uses the dry mixing method to mix the material from the line blend formula.

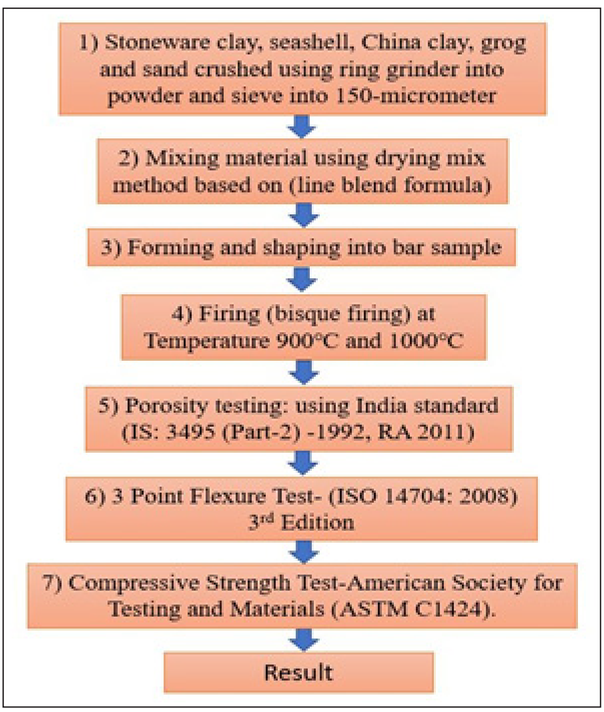



**Figure 1** Material preparation and experiment process

## Preparation of Mixing Material

To continue the study, the materials used were collected then cleaned and processed into a powder. Stoneware clay and seashells crushed using a machine (ring grinder) and then sifted using a 150-micrometre (sieve). Materials such as grog, sand and China clay were also used as additives in the tested samples.

**Table 1** Ingredients processed into powder

|  |  |  |  |  |
|---|---|---|---|---|
| **Stoneware Clay** | **Seashell Powder** | **Grog** | **Sand** | **China Clay** |

## Preparation of Formula

**Table 2** Formula of mixing material using line blend method

| Material | Formula | | | | |
|---|---|---|---|---|---|
| | FC-1 | FC-3 | FC-12 | FC-18 | FC-26 |
| **Stoneware Clay** | 1000g | 900g | 900g | 750g | 400g |
| **Seashell** | 0g | 100g | 50g | 150 | 150g |
| **Grog** | 0g | 0g | 0g | 50g | 150g |
| **Sand** | 0g | 0g | 50g | 50g | 150g |
| **China Clay** | 0g | 0g | 0g | 0g | 150g |
| **Total** | 1000g | 1000g | 1000g | 1000g | 1000g |

Table 2 shows the formula of mixing material using line blend method that was prepared to test the physical strength and porosity levels of stoneware clay with a mixture of organic waste as ceramic bodies. Each formula (FC) of the mixture of ingredients produced is in 1-kilogram weight. The ingredients were then mixed with water before undergoing physical experiments.

**Preparation of Bar Sample**

| No. | Picture | Description |
|---|---|---|
| 1. |  | Knead the clay until it is completely soft and easy to shape in addition to removing wind bubbles on the clay. |
| 2. |  | Flatten the clay using rollers until it forms a slab. The thickness must be based on the mold that has been prepared. |
| 3. |  | Using a metal mold, press on the surface of the clay slab until a clay bar is formed according to the size of the mold |
| 4. |  | Finally, each bar sample will be numbered/ code (FC) to facilitate the data collection process. Then, all samples were allowed to dry at room temperature before being firing in the ceramic kiln. |

**Figure 2** Preparation of bar sample (FC)

**Bisque Firing Sample 900°C and 1000°C**

Figure 3 shows the sample is fired in an electric kiln before being tested for porosity and strength test. The samples were fired at two types of firing temperatures 900°C and 1000°C.


**Figure 3** Sample fired in electric kiln

**Porosity Test (IS: 3495 (Part-2) -1992, RA 2011)**

The porosity test is an experiment performed to identify the rate of water absorption on the ceramic body sample after the biscuit firing process. In addition, another purpose of this porosity test is to determine the rate of the density of a ceramic body in identifying the rate of maturity of a ceramic body mixed with seashells after firing at a temperature of 900°C and 1000°C in ceramic kiln. For the calculation of this porosity test, the researcher used Indian standard: (IS: 3495 (Part -2) -1992, RA 2011).

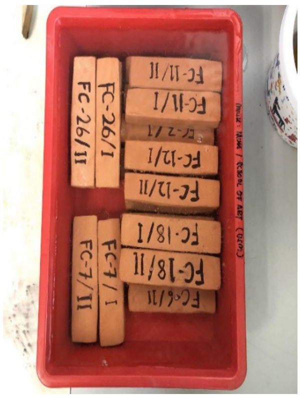
| No. | Picture | Description |
|---|---|---|
| 1. |  | After completion of bisque firing, record the dry weight of all bar samples. |
| 2. |  | Soak the bar sample in the basin with clean water for 24 hours. The water temperature must be at a rate of 27-29 °C. |
| 3. |  | Take a soaked bar sample and wipe the bar sample with a clean cloth. After 3 minutes, record the total wet weight. |
| 4. | $\text{Water absorption } (\%) = \frac{W_w - W_d}{W_d} \times 100$ | Calculate the total water absorption using the Standard Test Method formula (IS: 3495 (Part-2) -1992, RA 2011). |

**Figure 4** Porosity test procedure

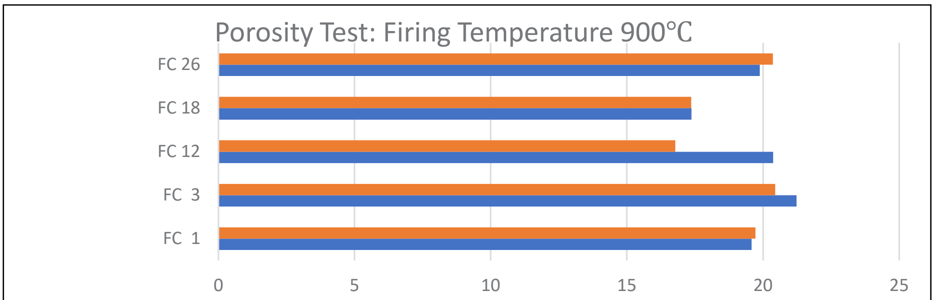
## Physical Strength Testing

In this study, physical strength test; Compression Test and 3 Point Flexure Test was performed using Gotech Universal Testing Machine (UTM) hydraulic machine.

**Figure 5** Gotech Universal Testing Machine (UTM)

## RESULT AND DISCUSSION

### Porosity test Temperature 900°C and 1000°C



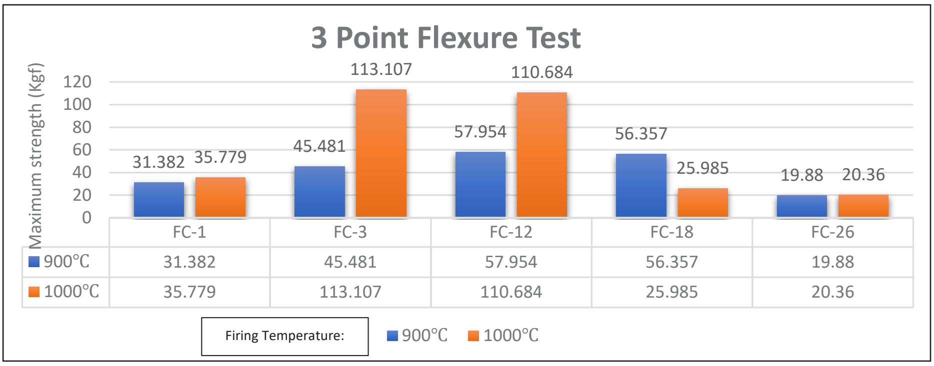

| | FC 1 | FC 3 | FC 12 | FC 18 | FC 26 |
|---|---|---|---|---|---|
| Temperature 1000°C | 19.72 | 20.45 | 16.78 | 17.36 | 20.36 |
| Temperature 900°C | 19.58 | 21.23 | 20.37 | 17.37 | 19.88 |

**Graph 1** Porosity test for firing temperature 900°C and 1000°C

Graph 1 shows the result for porosity level for two type of firing temperature of sample FC-1, FC-3, FC-12, FC-18, and FC-26. From the results of the experiment, all samples have porosity rates that are not too much different. Nevertheless, the highest porosity percentage rate for temperature 900°C is sample FC-3 with a total porosity 21.23 per cent. From these results, we can see that a mixture of 100-gram seashell powder in 900-gram stoneware clay is able to increase the porosity rate of clay body to help the porosity rate and pore formation on the internal structure of ceramic body when fired at 900°C. Similarly, at firing temperature 1000°C, FC-3 sample recorded the highest porosity rate 20.45 per cent while FC-18 recorded the lowest porosity rate for firing temperature 900 °C with a porosity rate of 17.37 per cent while sample FC-16 recorded the lowest porosity rate for a firing temperature 1000 °C which is 16.78 per cent.

## Physical and strength test

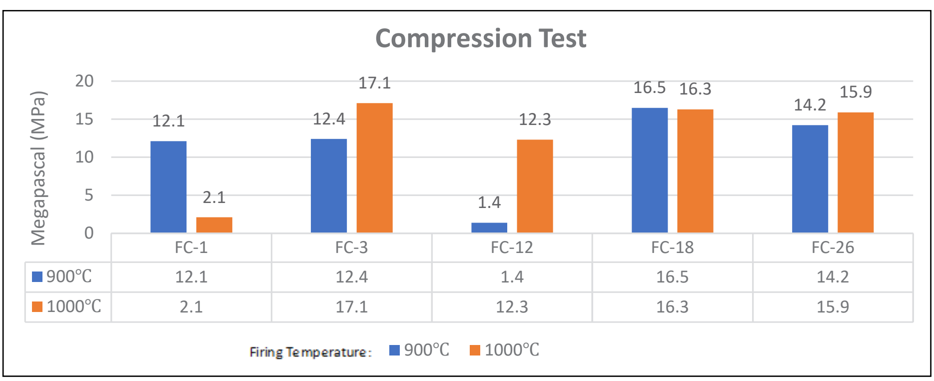
### 3 Point Flexure Test: (ISO 14704: 2008) 3rd Edition




**Graph 2** Physical and strength test result for firing temperature 900°C and 1000°C

Graph 2 above shows, the sample bar (FC) that recorded the highest maximum strength rate was FC-3 which was 113.107 (kgf) for a firing temperature of 1000°C while for the temperature of 900°C, FC-12 recorded a strength rate of 57.954 (kgf). In addition, it is also shown that the lowest pressure strength in this experiment is in the sample FC-26 which is 19.88 (kgf) for a firing temperature of 900°C, while 20.36 (kgf) for firing temperature 1000°C is also in the sample FC-26. The results of this experiment proved that the sample FC-3 and the sample FC-12 had achieved the best strength rate at the combustion temperature of 1000°C and proved that the seashell powder mixture reacted to the clay body strength factor at a certain firing temperature.

### Compression Test: American Society for Testing and Materials (ASTM C1424) Standard




**Graph 3** Compression test result for firing temperature 900°C and 1000°C

Graph 3 shows the results of a ceramic pressure strength test using the American Society for Testing and Materials standard (ASTM C1424) for a firing temperature of 1000°C. The experimental results show that the highest-pressure strength for 1000°C temperature is FC-3 with strength (17.1MPa) and followed by FC-18 (16.3MPa), FC-26 (15.9MPa), FC-12 (12.3MPa) and FC-1 (2.1MPa). The results of this experiment also show that FC-1 is the (FC) that has the lowest compressive strength among the 5 samples (FC) tested. Besides, Graph 3 also shows the results of a ceramic pressure strength test for firing temperature 900°C. The experimental results show that the highest-pressure strength for 900°C temperature is FC-18 with strength (16.5MPa) and followed by FC-26 (14.2MPa), FC-3 (12.4MPa), FC-1 (12.1MPa) and FC-12 (1.4MPa). The results of this experiment also show that FC-12 is the (FC) that has the lowest compressive strength among the 5 samples (FC) tested.

## CONCLUSION

In conclusion, from this experiment, it can be identified that the variable involved is the percentage of seashell powder mixed in the stoneware clay which will affect the porosity rate and strength rate after firing. This experiment has proved that the mixture of seashell powder with stoneware clay has been able to affect the strength of the ceramic body whether the firing temperature of 900°C or 1000°C. In the meantime, the firing temperature is also affecting the strength of ceramics mixed with seashell powder as can be seen in graph 3 and graph 2. However, the level of maturity or melting point that can be achieved by bar samples that have been mixed with seashell powder has also been affected by the presence of the element calcium carbonate found in seashells.

In addition, the porosity test has also shown that the presence of seashell powder and other elements can affect the porosity of the sample after firing at temperature 900°C and 1000°C, but the pressure strength is a little bit different and allows further research to identify this reaction in more depth. The results of this experiment have proved that the mixture of seashell powder with stoneware clay is able to increase the strength rate of ceramic body when the formula (FC-3) with a mixture 10% of seashell powder fired at a temperature 1000°C reaches a maximum strength of 113.107 (kgf) compared with the sample (FC-1) which was not mixed with seashell powder with a strength 35.779 (kgf).

Overall, this study proved a positive response to the strength of the ceramic body added with 100grams of seashell powder with 900grams of stoneware clay fired at temperature 1000°C. Therefore, it is hoped that this study can be utilized and become additional knowledge to students and ceramic art entrepreneurs to further innovate as well as study in more depth about the potential organic waste in the production of sustainable ceramic body formulations to save the environment without stopping to produce their work.

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