# The Manufacture of Tiles (1/4"x4"x4") Using Vigan Clay, Silica, and Ball Clay

VICTORIANO R. RAGASA, Ed.D.
RONALD AMANO

## ABSTRACT

*This study attempted to find out which of the different formulations of clay materials and substances using Vigan clay, silica, and ball clay would yield better quality of clay tiles in terms of drying shrinkage (measurement) and appearance during leather-hard stage and bisquit firing. It focused its investigation on four formulations of clay body using Vigan clay (V), silica (S), and ball clay (B) at different percentages/ proportions, namely: Formulation A (60-20-20 VSB); Formulation B (60-25-15 VSB); Formulation C (60-30-10 VSB); and Formulation D (60-35-05 VSB).*

*Results of the study showed that Formulation D yielded the best quality of clay tiles both in drying shrinkage (measurement) and appearance during the leather-hard stage and after bisquit firing. While the clay tile samples from the four formulations of clay body significantly differed in drying shrinkage (measurement) during leather-hard stage, they had slight difference in measurement during the leather-hard stage and after bisquit firing.*

## Introduction

### Background of the Study

Clay body is a mixture of clay and other earthen materials or mineral substances which are blended to achieve a specific material for ceramic purposes. Many clay materials found in the earth serve their purpose the way they are. These clay materials may be dug from the ground, kneaded with the right amount of water, and made into pottery without using any additional substance. Such clay materials are natural clay bodies. Sometimes, adjustments are made for better working properties. For example, an amount of sand, feldspar or silica, and other earthen materials are added to reduce shrinkage and lessen the tendency of the clay to warp and crack when dried or fired. This depends upon the characteristics of the clay. The potter, who adds more non- plastic material to his clay until it would dry without cracking and fired without breaking, makes a clay body. This is done by trial and error method or through experimentation until he arrives at a workable mixture or composition of the substances.

For convenience, all materials, which are made into clay bodies or fillers, are non-plastic materials like flint, grog or calcined clay, and fluxes as feldspar, frit, or silica. Plastic materials make the clay body pliable and easy to mold. The fillers enable it to dry out safely without warping or cracking, and to decrease the amount of shrinkage. The fluxes control the fusion or hardening point of the clay and make it hard to a satisfactory degree of density at any temperature used.

Bodies which are pressed from plastic clay are considered less pliable than those bodies which are found in other methods. In pressing, the clay must be soft enough to flow to the cavity of the mold while under pressure. Pressed ware is commonly handled immediate after pressing and must be strong enough to retain its shape. A thorough wedging is required to assure a complete mixing of the coarse ingredients, to drive out the trapped **air,** and to increase plasticity of the material.

This study was conducted to describe the process of plastic wet pressing in clay tile production done in the Ceramics Research and Productivity Center (CRPC) University of Northern Philippines (UNP), Vigan, Ilocos Sur. It was the first investigation conducted in the manufacture of clay tiles using Vigan clay, silica, and ball clay found most particularly in Vigan, Ilocos Sur.

## Objectives

The study attempted to identify the best mixing formula for clay body using Vigan clay, silica, and ball clay in the manufacture of good quality clay tiles. It sought to:

1. Determine the formulation of clay body that would yield better quality of clay tiles in terms of drying shrinkage (measurement) and appearance during leather-hard stage.

2. Determine the formulation of clay body that would yield better quality of clay tiles in terms of drying shrinkage (measurement) and appearance after bisquit firing.

3. Find out the significant difference in drying shrinkage (measurement) among the products of the different formulations of clay body.

## Scope and Delimitation

This study was focused on the manufacture of clay products, specifically the clay tiles.

It was limited to the analysis of the following:

I. Four mixing formulations of clay body (Table 1) to produce better quality of clay tiles in terms of drying shrinkage (measurement) and appearance during leather-hard stage.

**Table 1. Mixing formulations of clay body analyzed in the study.**

| FORMULATION | CLAY MATERIAL | Percent) | |
|---|---|---|---|
| | VIGAN CLAY (V) | SILICA (S) | BALL CLAY (B) |
| A | 60 | 20 | 20 |
| B | 60 | 25 | 15 |
| C | 60 | 30 | 10 |
| D | 60 | 35 | 05 |

2. Four mixing formulations of clay body (Table 1) to produce better quality of clay tiles in terms of drying shrinkage (measurement) and appearance after bisquit-firing.

## Significance of the Study

It was deemed that the results of the study would serve as information guide for ceramics or pot makers and would also contribute to the attainment of the UNP thrusts in technology development, particularly in the utilization of clay products in the infrastructure projects of the university.

## Review of Related Literature

Navarro (1980) states that wet clay can be molded and shaped, can retain its shape when dried, and can be fired to become a hard and permanent article. This makes clay a valuable raw material for civilization. There are eight physical properties of unfired clay which control their usefulness, namely:

1. **Plasticity.** This is the property which enables clay to be distorted without rupture and to retain this distorted shape after the force has been removed. It is the property which makes it possible to mold clay into any desired shape.

Various tests have been made to detennine the relative plasticity of two kinds of clay. The simplest method of testing the plasticity of clay is the feel test. One who is familiar with the feel of plastic clay can estimate the relative plasticity of two kinds of clay by working on them with his hand.

The amount of water necessary to develop the degree of maximum plasticity is often taken as the measure of the plasticity of clay. The fonnula is:

$$\%H_2O \text{ of plasticity} = \frac{\text{Wet weight} - \text{Dry weight}}{\text{Dry Weight}} \times 100$$

2. Power of suspension. This is the property of clay which enables it to maintain itself and other materials suspended in it by a liquid. Fine-grained clay will remain suspended in water for hours without signs of settling. If the grains are coagulated into larger particles by the addition of flocculating electrolytes (acids, borax, and magnesium sulfate), they will settle more rapidly. When the electrolyte has a deflocculating carbonate and sodium silicate) it will increase the dispersion and produce a more rapid suspension of the clay.

3. Texture. The plasticity, strength, ease of drying, and character of fired piece are greatly affected by the size and shape of the clay particles. This is called the texture of the clay. Most types of clay contain grains of sand and shale of sufficient sign visible to the naked eye, but majority of clay particles are so small that it is difficult to distinguish them with the aid of a microscope.

4. **Shrinkage.** The removal of both water film and absorbed water results in shrinkage. In addition to the absorbed water film, excess water will fill the pores between the clay grains. The last traces of mechanically combined water in clay can be removed only by heating the clay about the boiling point of water (1OOC).

Clay materials differ greatly in their shrinkage. The degree of variation in the drying shrinkage of clay is similar to the variation in the amount of water necessary to develop their plasticity. The greater the plasticity of clay, the greater is the water absorbed and the greater the thickness of the film, the greater is the shrinkage when it is dried.

*5.* **Strength.** The degree of intensity of compactness is strength. The usefulness is often controlled by its strength when dry. The strength of dried clay depends on several factors: a) the size of plastic and non-plastic particles; b) the amount of fine- grained clay substances that are free from impurities which are white in color.

It is impossible to predict in all cases the color of the clay after it is fired. Generally, clay which is brown or red have sufficient vion content to fire the red color. Black clay bum into white, cream, or buffer red. The black color is due to carbon which bums out in firing. The color of the fired clay is due to the other impurities that would not be identified before firing because their effect on the color of the clay is hidden by the carbon.

6. Burning shrinkage and behavior in firing. When clay is fired, additional shrinkage occurs and may vary between limits depending on many factors such as: kind of clay present, the fineness of the clay, the amount of organic material in the clay, the method of forming the clay, and the temperature in which they are fired. In general, plastic clay shrinks more, both in drying and in burning than non-plastic clay. Organic materials in a clay is generally accompanied by increasing the burning shrinkage. The shrinkage of clay increases as the temperature increases within a certain limit, that is up to the temperature of which fusion and decomposition take place. Clay varies widely in their burning behavior, i.e., the maximum shrinkage may be reached in some clay at a comparatively low temperature, while much higher temperature will be required by others. One clay matures at a high temperature and has less shrinkage than another which matures at a low temperature.

The burning shrinkage, like the drying shrinkage, is a very important property of clay. If excessive, it causes distortion, warping and cracking of the ware. In any case, it is important to know the burning shrinkage to be able to control the size of the finished article, not only when using the clay alone but also in other substances containing clay.

## Hypothesis

The researchers hypothesized that at .05 level of significance there is no significant difference among the products of the four mixtures/formulations of Vigan clay, silica, and ball clay in terms of drying shrinkage (measurement).

## Methodology

**Research design.** The experimental method of research was used in the study. Five replications were done using the four formulations of clay body. Procedures were keenly observed and the data from each replication were noted down.

**Materials and tools/equipment needed.** Table 2 presents the materials and tools/ equipment needed in this study and their description/uses.

Table 2. The materials and tools/equipment needed in the study **and the** description/ uses.

| MATERIAL AND TOOL/EQUIPMENT | **DESCRIPTION/USE** |
|---|---|
| Basin | For putting and soaking the ingredients of clay body. |
| Clay body | It is a mixture of Vigan clay, silica, and ball clay with the required amount of water. |
| Can/Container | For putting water needed during the process of forming the articles. |
| Foot rule | For measuring the size of the article (tile) |
| Kiln | A high temperature installation used for firing ceramic wares or for calcining or sintering |
| Magnetic wire (fire) | For cutting the excess clay in the mold. |
| Mold | A tool used in moulding the clay articles (tile) |
| Paddle | A tool used in pressing the articles (tiles) after they have been formed and soft-dried. |
| Pallet | A board used for putting the articles after forming them |
| Table./Board | Used as the base during the process of kneading the clay body and in forming the articles (tile) |
| Slab | It is used for soft drying the clay body |
| Weighing scale | For measuring the weight of the ingredients of the clay body |

Technical description of the process. Basically, three steps were followed in clay tile production from the plastic wet pressing until such time that results were obtained, namely: 1) preparation of clay body; 2) plastic wet pressing on mold; and 3) firing.

The preparation of the clay body was done through experimentation of four formulations in order to find out which among the formulations could produce clay tiles, 1/4"x4"x4" that have least shrinkage and best texture.

The materials needed in the formulation of clay body were: Vigan clay (V), silica (S), and ball clay (B). The formulations of the clay body are shown in Table 1.

The preparation of the clay body was done through the wet method. This involved the following techniques: dry fine gro und silica; crushing plastic clay (Vigan clay); measuring and mixing Vigan clay, silica, and ball clay with the required amount of water (manual); soaking overnight; purification of mixture (manual screening, 40 mesh); partial dehydration; and kneading (manual).

The steps in the preparation of clay body were the following:

1. Prepare all materials needed.
2. Weigh the required amount of Vigan Clay and put it in a container.
3. Weigh the required amount of silica and put it over the Vigan clay.
4. Weigh the required amount of ball clay and put it over the silica.
5. Add enough water to the clay and let it stand overnight. This will allow water to penetrate deeply into the clay granules in order to avoid lumps.
6. Smoothen the surface by sprinkling water and press it gently with the hand.
7. Lift one cover of the mold and slightly press the article in it.
8. Transfer the article to the pallet and let it dry until it is ready for paddling.
9. With wooden paddle, press the article on its surface and four sides.
10. Sprinkle water over the surface of the article and put it on the side of the pallet, moving it from one end to the other with slight pressing. This is done repeatedly to ensure a smooth and flat surface.
11. Sponge over the surface and the sides of the article.
12. Transfer the article to the pallet for air drying until it is ready for bisquit firing.

Bisquit firing was done using the UNP CRPC electric kiln. Traditional potters in the rural areas use the open-pit firing. Among industries and school, kiln is preferred for special purposes.

The purpose of firing was to fuse the body so that it would have the desired qualities of strength and density while retaining its shape and structure. Bisquit firing was done below the maturing temperature of the clay body and the articles were fired at 100OC.

In addition to the clay tile samples, other ceramic articles were loaded in the kiln to its maximum capacity to save on electricity.

**Statistical treatment of the data.** The clay tile samples were tested and treated statistically. To determine the average measurement of the clay tile samples from the four formulations of clay body, the mean was used. To determine the significant differences in the drying shrinkage of clay tile sample during leather-hard stage and after bisquit firing, the one-way analysis of variance (one-way ANOVA) was used.

# Discussion of Results

## Quality of Leather-hard Clay Tiles

The quality of the clay tiles during leather-hard stage was measured in terms of drying shrinkage (measurement) and appearance.

**Drying shrinkage (measurement).** Table 3 shows the measurement of the clay tile samples from the four formulations of clay body in the five replications. The data show that the average clay tile samples in the four formulations had almost the same measurement. Formulation D (60-35-05 VSB) yielded an average clay tile sample measuring 3 15/16 in, the highest mean, while Formulation C(60-30-10 VSB) yielded an average clay tile sample measuring 3 ¼ in, the lowest mean. Formulation A (60-20-20 VSB) and Formulation B (60-25-15 VSB) yielded average clay tile samples with equal measurement (3 13/16 in).

Table 3. Drying shrinkage (measurement) of clay tile samples from four formulations of clay body during leather-hard stage.

| **REPLICATION** | **MEASUREMENT PER FORMULATION** (in) | | | |
|---|---|---|---|---|
| | **A** (60-20-20 VSB) | **B** (60-25-15 VSB) | C (60-30-10 **VSB)** | **D** (60-35-05) |
| 1 | 3 7/8 | 3 13/16 | 3 13/16 | 3 7/8" |
| 2 | 3¼ | 3 7/8 | 3 13/16 | 4" |
| 3 | 3 13/16 | 3 15/16 | 3¼ | 4" |
| 4 | 3 13/16 | 3 7/8 | 3 7/8 | 3 7/8" |
| 5 | 3 13/16 | 3 13/16 | 3 13/16 | 3 7/8" |
| MEAN | 3 13/16 | 3 13/16 | 3¼ | 3 15/16° |

To test whether or not the drying shrinkage (measurement) of the clay tile samples from the four formulations of clay body were significantly different, one-way ANOVA was used. The ANOVA table shows that the computed F-ratio (5.27) was higher than the tabular F-ratio at .05 level of significance (3.24). This indicates that there was a significant difference in the drying shrinkage of the clay tile samples from the four formulations of clay body during leather-hard stage (Table 4). The significant difference implies that with 60% Vigan clay, the higher the proportion of silica and the lower the proportion of ball clay, the better the quality of the product; and the lower the proportion of silica and the higher the proportion of ball clay, the poorer the quality of the product.

**Table 4. Analysis ofvariance of drying shrinkage (measurement)** of clay **tile samples during leather-hard stage.**

| SOURCE OF VARIATION | SUMOF SQUARES | df | MSS | F-RATIO |
|---|---|---|---|---|
| Between groups | .04552 | 3 | .01517 | 5.27 |
| Within groups | .04636 | 16 | .00288 | |
| Total | .09788 | 19 | | tv.05=3.24 |

**Appearance.** Table 5 presents the appearance of the clay tile samples from the four formulations of clay body during leather-hard stage. Almost all the clay tile samples were relatively good for their surfaces did not show any indicator of either warping (distortion) or cracking. However, clay tile samples in two replications of Formulation A (60-20-20 VSB) showed signs of warping on their surfaces.

Table S. Appearance of clay tile samples from four formulations of clay body during leather-hard stage.

| REPLICATION | APPEARANCE PER FORMULATION | | | |
|---|---|---|---|---|
| | **A** (60-20-20 VSB) | **B** (60-25-15 VSB) | C (60-30-10 VSB) | D (60-35-05 VSB) |
| 1 | Good | Good | Good | Good |
| 2 | Good | Good | Good | Good |
| 3 | Good | Good | Good | Good |
| 4 | Warped | Good | Good | Good |
| 5 | Warped | Good | Good | Good |

## Qualities of Bisquit-fired Clay Tiles

Similar to the leather-hard clay tiles, the quality of the clay tiles after bisquit firing was measured in terms of drying shrinkage (measurement) and appearance.

Drying shrinkage (measurement). Table 6 shows the measurement of the clay tile samples from the four fonnulations of clay body in the five replications after bisquit firing. The mean measurement of the clay tile samples per formulation of clay body indicates that Formulations Band D yielded bigger tiles ( 3 7/8 in) than Formulations A and C (3 % in). However, Table 7 shows that the computed F-ratio in the ANOVA (1.21) was lower than the tabular F-ratio at .05 level of significance (3.24). This indicates that there was no significant difference in the drying shrinkage of clay tile samples from the four formulations of clay body after bisquit firing. This was so because the significant difference was already shown during the leather-hard stage. This implies that after bisquit firing the clay tiles, their measurements do not differ significantly since the temperature set for firing is constant and does not fluctuate.

Table 6. Drying shrinkage (measurement) of clay tile samples after bisquit diring.

| REPLICATION | MEASUREMENT PER FORMULATION (in) | | | |
|---|---|---|---|---|
| | A (60-20-20 VSB) | B (60-25-15 VSB) | C (60-30-10 VSB) | D (60-35-05 VSB) |
| 1 | 3 13/16 | 3 13/16 | 3% | 3 7/8 |
| 2 | 3%4 | 3 7/8 | 3% | 3 7/8 |
| 3 | 3% | 3 7/8 | 3% | 3 15/16 |
| 4 | Broken | 3 7/8 | 3 13/16 | 3 7/8 |
| 5 | 3%4 | 3 13/16 | 3% | 3 7/8 |
| MEAN | 3¾ | 3 7/8 | 3% | 37/8 |

Table 7. Analysis ofvariance of drying shrinkage (measurement) of clay tile samples after bisquit firing.

| SOURCE OF VARIATION | SUMOF SQUARES | dr | MSS | F-RATIO |
|---|---|---|---|---|
| Between groups | 2.5864 | 3 | .8621 | 1.21 |
| Within groups | 11.3545 | 16 | .7097 | |
| Total | 13.9409 | 19 | | $t_{¥}$.05 = 3.24 |

**Appearance.** Table 8 shows the appearance of the clay tile samples from the four formulations of clay body after bisquit firing. Formulation D yielded the highest rating for appearance among the formulations for almost all the clay tile samples were rated good; only the sample in the second replication was slightly warped on the surface. Formulation C also yielded tile samples of good appearance in three replications but slight warping was shown in two replications. Fonnulation B yielded less clay tile samples that had good appearance than those which were slightly warped. Fonnulation A yielded a tile sample rated good in only one replication; one was broken; two were slightly warped; and one was heavily warped.

Table 8. Appearance of tile samples from four formulations of clay body after bisquit firing.

| REPLICATION | APPEARANCE PER FORMULATION | | | |
|---|---|---|---|---|
| | **A (60-20-20 VSB)** | B **(60-25-15 VSB)** | C (60-30-10VSB) | D (60-35-05 **VSB)** |
| 1 | Good | Good | Good | Good |
| 2 | Warped (slight) | Warped (slight) | Warped (slight) | Warped (slight) |
| 3 | Warped (slight) | Warped (slight) | Warped (slight) | Good |
| 4 | Broken | Warped (slight) | Good | Good |
| 5 | Warped (heavy) | Good | Good | Good |

## Summary of Findings

Data on drying shrinkage (measurement) and the appearance of the clay tile samples during leather-hard stage and after bisquit firing revealed that:

1. Among the clay tile samples from the four fonnulations of clay body during leather-hard stage, Fonnulation D (60-35-05 VSB) yielded the highest average measurement with a mean of 3 15/16 in while Fonnulation C(60-30-10 VSB) yielded the least average measurement with a mean of 3 ¼ in.

2. According to appearance during leather-hard stage, clay tile samples from Formulations B (60-25-15 VSB), C (60-30-10 VSB), and D (60-35-05 VSB) were rated good.

3. After the clay tile samples had been bisquit fired, Formulations Band D yielded higher average measurement ( 37/8 in each) than Formulations A and C (3 ¼ in each).

4. According to appearance after bisquit firing, sample tiles from Formulation D got the highest rating because four samples were rated good and one was rated slightly warped. Formulation C got second rating with three samples rated good and two, slightly warped. Fonnulation A and B got the lowest rating in appearance among the four formulations.

## Conclusions

The above findings were the bases for the following conclusions:

1. Clay tile samples from the four formulations of clay body slightly differed in drying shrinkage during leather-hard stage and bisquit firing.
2. Clay tile samples from the four formulations of clay body did not differ in appearance during leather hard-stage but differed greatly after bisquit firing.
3. Formulation D (60-35-05 VSB) yielded the best clay tiles among the four formulations of clay body.

## Recommendations

1. To enable the UNP Ceramics Research and Production Center to produce the needed clay tiles in the UNP infrastructure projects, the UNP administration should hire one laborer who is an expert in making tiles.
2. To alleviate the income of clay tile makers particularly in Vigan while considering the welfare of the clay tile buyers, the government should do its role in the proper management of the commodity, as follows: a) It should impose price standardization programs. b) The technology should be improved and a kiln should be established in the clay tile makers' vicinity, c) Cooperative marketing should be initiated to prevent the existence of middlemen who sell the tiles at high prices.
3. Other studies should be conducted relative to clay tile production so that the ceramics articles would be improved.

## References

**COSTALES, FEDERICO** and **OLSON, DELMAR.** 1959. Ceramics for Schools and Industry in Developing Countries. Manila, Philippines.

**NAVARRO,** MANUEL. 1980 A Handout on Physical Testing of Ceramic Raw (Clay) Materials. Paper presented at the Seminar on Ceramics, Taguig, Metro Manila, Philippines.

**SPEIGHT,** CHARLOTTE F. 1976. Hands in Clay: An Introduction to Ceramics. U.S.A.: Mayfield Publishing Co.