International Journal of Sciences: Basic and Applied Research (IJSBAR)

ISSN 2307-4531
(Print & Online)

http://gssrr.org/index.php?journal=JournalOfBasicAndApplied

Examining the Quality of Local Omani Clays for Ceramic Slip Casting in Art Schools: Testing Deflocculant, Specific Gravity, and Viscosity

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Abstract

Ceramicists at art schools are usually fascinated by the basic processes they use. Most of them have developed their own pottery hand building techniques, constructed their firing kilns, and even composed their individual clays and glaze recipes in laboratories. Slip casting is one of the techniques used in forming ceramics worldwide, where liquid clay is cast in a plaster mold to make ceramic pots. In fact, most educational art schools, ceramics factories, and pottery craft enterprises in Oman use expensive imported clays to cast in plaster molds. Considering recent developments in ceramic making fields, it is becoming extremely difficult to ignore the importance of developing local slip casting clays to support both the educational and industrial ceramic and pottery fields within a particular region. By examining the Alanwar Ceramic Tiles Plant (ACTP) sample of local clay, the experimental work presented here provides one of the first investigations into how educational and industrial enterprises can take advantage of local clays to produce slip casting slurries.

Keywords: ACTP clay; slip casting; deflocculant; gravity; and viscosity.

1. Introduction

Slip casting has been defined as a "pottery-forming process which uses molds to give the forms and uses liquid clay" [1].

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Ceramicists pour slip (liquid clay slurry) into plaster molds and let it sit; then, the plaster absorbs water from the slurry building up in a layer against the mold surface. After the ceramicist is satisfied with the thickness of the formed layer, the slurry is poured back out of the mold. After several hours or sometimes even a day, the clay object slowly stiffens, shrinks, and pulls away from the plaster mold [2]. There is then an ion exchange between the plaster mold and the liquid slurry which helps to stiffen the cast pot [1]. Although it is essentially an industrial production technique, slip casting is used creatively by a number of individual ceramics artists [3]. It has some advantages as a pottery forming technique, especially given that it allows for control of pot thickness more than other pottery making methods. One of the reasons that ceramic industries prefer the slip casting technique is the standardization of a clay slurry recipe, according to which most ceramists compose their slips with 50% talc and 50% ball clay, adding smaller amounts of other materials according to their required qualities (e.g., firing temperatures or clay color). For example, in the Sultan Qaboos University Ceramic Laboratory (SQUCL), ceramics researchers developed a slip casting slurry in 2017 including bone ash (50%), Cornish stone (25%), and China clay (25%). This recipe was a perfect sample, especially when ceramicists are required to reach high firing temperatures, and pots made by this recipe can withstand a temperature of 1280°C. However, the negative aspects of this recipe were that all of the raw chemical materials used to compose it were expensive and imported to Oman from outside of the country. In a recent study, earthenware clays created by the Alanwar Ceramic Tiles Plant (ACTP) were produced locally from six different raw materials with various chemical compositions. The final clay recipe produced by the ACTP was mixed with dry raw materials in different ratios, ranging from 10% to 28% [4]. This clay recipe contained different types of sands and pure red clays gathered from various Omani districts. As is the case at all ceramic plants, the raw materials were first ground in large ball mills and then mixed homogenously in the main (and largest) ball mill [4]. For this project, the researcher aimed to use the final ground clay recipe which is composed of the different percentages as shown in table (1) below:

Table 1: The ACTP clay recipe

Raw Material	Percentage (Ratio)
General sand	14%
Scrap (fired ceramic grogs)	10%
Wadi Ghul clay	18%
Mahadha clay	28%
Lawa sand	14%
Al Hamra clay	16%

The above composed recipe was transferred to the SQUCL for testing and development for a completely different use; whereas originally the ACTP developed this recipe for ceramic tiles, the aim of this project was to use it for slip casting pottery.

2. Laboratory Experiments

Usually after the clay is extracted from mines, it is brought directly to the pottery for further treatment. This is because some raw clays contain so much sand that the true clay content found in primary clay deposits may be only 15% or less [5]. For this project, we had a special case where the clay sample used was composed of materials from many locations. To guarantee the availability of clay in the SQUCL, a large quantity of the basic sample was obtained from the ACTP. To clean the sample, the obtained clay was mixed in water until the material at the bottom of the container was only comprised of sand. Then, the clay slurry was relocated into another settling container. After the clay had settled in the settling container, the clear water on top could be transferred smoothly. The clay was then left in the settling container until it was stiff enough to be removed for drying. After drying, the whole sample was crushed and ground into a very fine powder (sieve mesh: 160 holes per inch). The main sample was then ready to be divided into smaller quantities for testing, and the researcher conducted three main tests as follows.

2.1. Test 1: Pure Clay Sample (without Additions)

The abovementioned list of elements included in the ACTP clay was converted into a clay-body recipe using the designated percentages to target the desirable characteristics. The first testing recipe and experiment involved the use of pure clay powder without any other additions to examine its originality and quality. This process included the laboratory steps shown in Figure 1: A–C and Figure 2: D–F:

1. Grinding the clay powder: The pure clay powder was ground into a dry, clean porcelain mortar.
2. Sieving the dry clay powder: After grinding all of the dry clay powder until there were no chunks left, and with no loss of any contents along the way, all extracted powder passed through a ceramic sieve (mesh: 160 holes per inch).
3. Measuring by scale: By using a small electronic scale, the amount of sieved clay powder was measured, and this was poured into the plastic container for the mixing stage. At this point, the researcher extracted a random sample of 150 grams for the naked slip casting test.
4. Mixing: By using a liquid measuring container, 150 ml of water was added to the 150 grams of the selected sample. Then, the produced slip was shaken very well and left in the laboratory for one night.
5. Slip casting the plaster mold: After one day, the well-mixed clay slip was poured into a plaster mold to shape it into a ceramic piece.
6. Extracting ceramic piece from the plaster mold: The formed ceramic piece needed to cast quickly by building up a layer of clay against the mold walls while shrinking away and holding together as an extracted piece.

Figure 1: Laboratory preparation stages of (A) grinding, (B) measuring, and (C) mixing (SQU-Ceramics Lab).

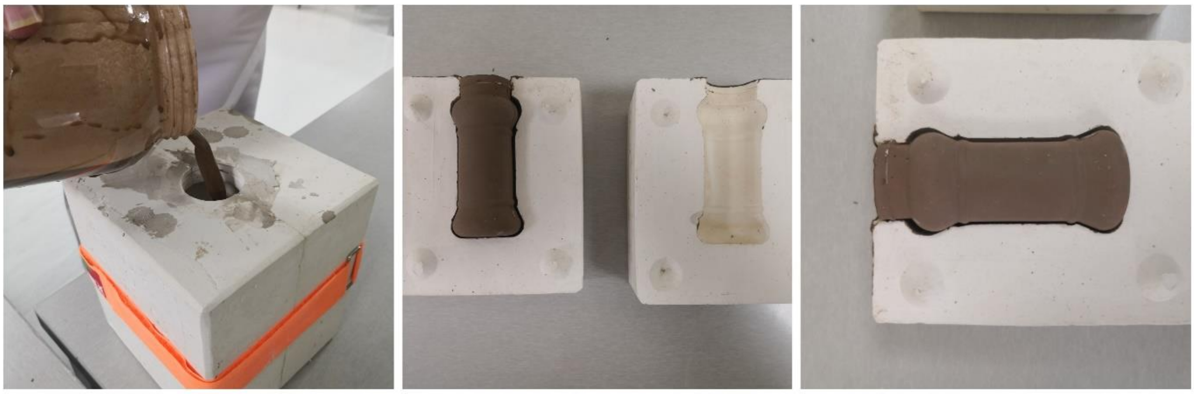

Figure 2: Laboratory preparation stages of (D) slip casting, (E) opening the mold, and (F) extracting the casted piece (SQU-Ceramics Lab).

2.2. Test 2: Clay Sample (with Sodium Carbonite and Sodium Silicate)

The second testing recipe consisted of the pure clay powder with two other additions to examine the quality in comparison to the results of the pure clay test. This process included the following laboratory steps (Figure 3):

1. Measuring by scale: By using an electronic measuring scale, the amount of sieved clay powder was measured and poured into a plastic container for the mixing stage. For this test, the researcher increased the sample quantity of dry powder clay to 300 grams for the second slip casting.
2. Deflocculant (soda ash and sodium silicate): The researcher used the percentages suggested by **Norsker** and Henrik to add both soda ash and sodium silicate as a deflocculant; 5 g of soda ash and 15 g sodium silicate were added to 200 ml water, which equated to 0.01 g deflocculant for each 1 ml water. As a result, each 1 ml of solution added to 1 kg of solid material meant an addition of 0.01% deflocculant. For this project, the researcher used Potterycrafts Ltd. Sodium Silicate Na2O (SiO2), which is a stronger de-flocculent than the P3343 commonly used in the preparation of casting slips, particularly for earthenware slips. Also, Potterycrafts Ltd.'s soda ash was comprised of Na2CO3 for this project, which is considered as a deflocculant in the preparation of casting slips when used in combination with sodium silicate.
3. Mixing: By using a liquid measuring container, 300 ml of water was added to the 300 grams of the selected sample. Then, the produced slip was shaken very well and left in the laboratory for one night.
4. Slip casting the plaster mold: After one day, the well-mixed clay slip was poured into a plaster mold for shaping into a ceramic piece.
5. Extracting the ceramic piece from the plaster mold: The formed ceramic piece needed to cast quickly by building up a layer of clay against the mold walls, rapidly shrinking away, and holding together as an extracted piece.

Figure 3: Second test with deflocculants, including (A) sodium silicate, (B) soda ash, and (C) the extracted casted piece (SQU-Ceramics Lab).

3. Evaluating Slips

3.1. Deflocculant

Many researchers have utilized the addition of deflocculants to elevate the quality of slips for slip casting forming techniques. By adding both soda ash and sodium silicate to clay, the potter can minimize the quantity of water content in the slip. In fact, there are no confirmed percentages for soda ash and sodium silicate compared with the designated percentages for clay powder, but most potters estimate the additions of these materials from an informed perspective and observe their impact on the slip directly. Instead of these two added materials (soda ash and sodium silicate), many potters prefer to use Darvan (811 or 812) for two reasons. First, Darvan can function as a deflocculant on its own as a single material, where, as mentioned before, soda ash and sodium silicate must be added together to function in this way. Second, Darvan can save the quality of molds for longer use because it is less capable of attacking plaster (gypsum). In contrast to all of the other available deflocculant materials, Epsom salt (magnesium sulfate), when employed in making ceramics casting slips as a flocculant, makes slips thicker by electrostatically charging particles so that they are more attracted to each other. For this project, the researcher did not use Epsom salt, but it is worth recalling that the material can help potters in making engobe into paint pottery. As sections 2.2 and 2.3 show, there is a significant difference between the pure slip and the deflocculated slip. It seems to be particularly important for industrial use to add deflocculants, but for educational purposes, pure slips can still satisfy potters and ceramics educators.

3.2. Testing Specific Gravity

In ceramics, specific gravity is defined as the comparison of a liquid's weight with the weight of an equal volume of water by using an accurate electronic scale. This can be measured such that one water gram of weight is equal to the volume of one milliliter. Specific gravity is particularly important in the production of both casting slurry and glaze slips where an as-low-as-practical water content is required. Ceramicists, artists, and ceramic students normally aim for around 1.75, but for industrial purposes 1.8 or higher is essential. After the first testing of the ACTP clay (slip), the researcher noted that the slip settled in the bottom of the mold (Figure

4). The first step was to isolate the defect of settling by measuring the specific gravity of the slip. This allowed the researcher to determine if the issue was with the percentage of water or the deflocculant in slip.

Figure 4: First test of the ACTP clay (slip) showed the defect of settling in the bottom of the mold, so the extracted piece of ceramic had a very thick bottom (SQU-Ceramics Lab).

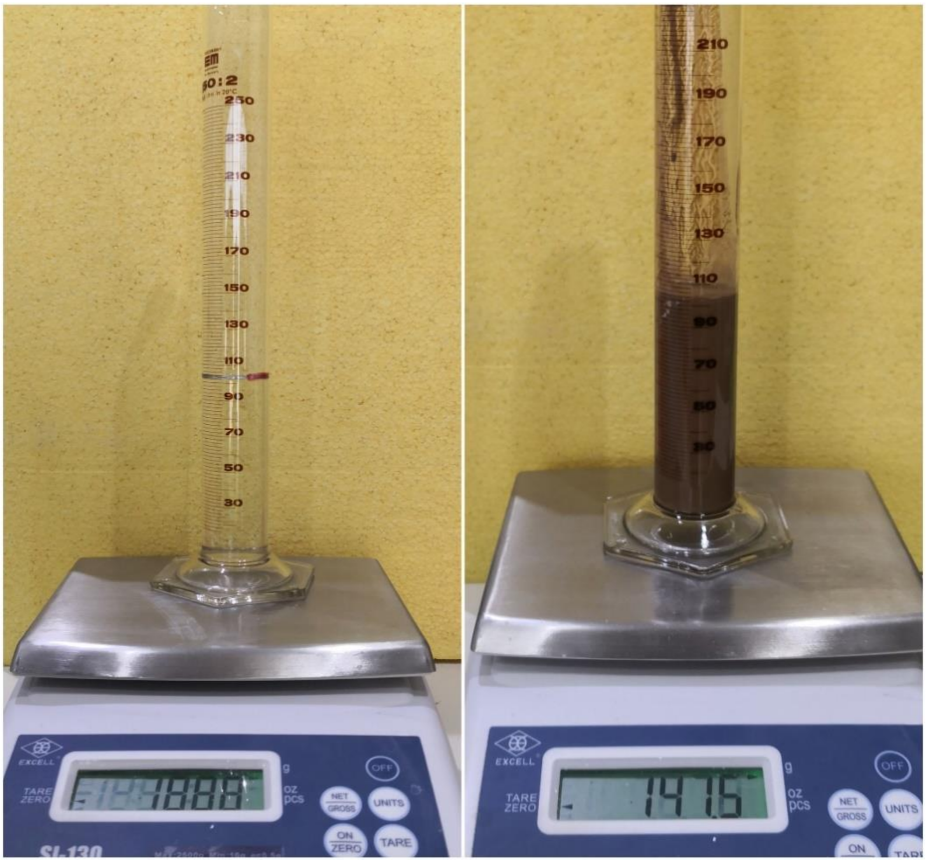

Figure 5: Measuring specific gravity of the ACTP clay slip (SQU-Ceramics Lab).

For this project, the researcher counterbalanced the empty graduated cylinder to zero on the electronic scale, and then the cylinder was filled with water to 100 ml (CC). Afterwards, the same cylinder was filled with the prepared red clay slip to the same level of 100 ml (CC), and then the slurry weight was divided by the water weight. In this case, the weight of the ACTP clay slip filled to the level of 100 ml (CC) was 141.5 g, and by dividing 141.5 by water weight of 100 ml (100g), the difference between weights, which is considered the specific gravity, was 1.4. Thus, decreasing the quantity of water can allow the specific gravity to reach at least 1.7, which is considered the standard for artist specifications and educational purposes.

3.3. Viscosity

By measuring the thickness or runniness of the casting slip, it is possible to evaluate the level of viscosity. A casting slip that has a high viscosity is usually thick and slip that has a low viscosity is called a fluid. For this project, to measure the viscosity of a casting clip, the researcher used a Ford viscosity cup. This cup is a gravity tool that allows for the timed flow of a liquid passing through a hole located at the bottom of the cup. With the target of a 40 second drain, the ACTP slip drained in 42 seconds (in fact, the same Ford viscosity cup drains water in 10 seconds).

Figure 5: Ford cup used to measure the viscosity of slip casting liquid.

4. Conclusion and Recommendations

The present study was designed to examine the quality of the ACTP clay to be used in slip casting ceramics for both educational and industrial enterprises. The most obvious finding to emerge from this study is that the ACTP clay can be used as a pure clay without any modifications or additions, but by adding deflocculants such as soda ash and sodium silicate, its quality for casting ceramics artworks is quite astonishing. In fact, this study has raised important questions about the possibility of using local clays for slip casting rather than importing clays for both educational and industrial purposes. Nonetheless, these results must be interpreted with caution and several limitations should be borne in mind. The first is that the chemical analysis for each component of ACTP clay is not provided in this for commercial trademark purposes. Also, these components usually have some impurities, and once these impurities become in high quantities the results will not be as same as reported in this research. Considerably more work will need to be done to explore the quality of local clays. Finally, and perhaps most importantly, this investigation's findings may be more valuable for small and medium ceramics and pottery enterprises in their limited production lines.

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