

Creating Matte and Opaque Stable Colored Glazes on Local Omani Earthenware Pottery: Testing White Zircon Borax Frit Glaze Recipes

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Abstract

The ability of Omani local pottery earthenware to accept low- and medium-temperature fired glazes can face technical difficulties. The impurities included in the clays extracted from local fields, especially iron oxide, are a noted weakness that affects painting the local pottery with shiny, opaque, or matte glazes. Previously published research conducted by the researcher on Omani earthenware clays focused on finding a special transparent, shiny, and stable glazing recipe, but few studies have provided matte and opaque glazing recipes that are technically suitable for local Omani clays. By using laboratory-based experimental methodology, this research will investigate the possibility of using White Zircon Borax Frit (WZBF) to develop matte and opaque stable glazes that are suitable with local Omani pottery clay bodies. In the end of this experimental research, the purpose of this project is to develop applicable glazing recipes to be used for painting pots made by Omani clays.

Keywords

Earthenware Clay, Matte Glazes, WZBF, Oman

1. Introduction

Opaque glazes are used to hide body surface defects, including undesired substrate colors, to supply pleasant and appropriate aesthetic expression, and to provide adequate mechanical properties to ceramic industry products [1]. This has led ceramicists to use types of frits that can provide opaque glazes to ceramic industry products or to pottery in art education and crafts. Generally, frits are essential ingredients in most industrial glazes which mature at temperatures below 1150°C [2]. Because frits are more stable and are appropriate constituents

for producing accurate results, they have become the best option for ceramics in general, and for industrial use specifically. Instead of using raw glazes, fritted ones have the ability to reduce melting temperatures. Therefore, the maturation time of glazes will be shorter, and the product's surface will be smooth, stable, and bright.

Today, White Zircon Borax Frit (WZBF) is an important frit used for producing opaque glazes. Zircon, also called zirconium silicate by ceramicists, is considered the main opacifier in producing the glossy and opaque glazes that are often used in the wall tile industry [3]. According to Yekta *et al.* (2006) [4], "In the traditional opaque glazes used in the wall tile industry, opacity usually originates through hardening the glass matrix by adding high amounts of zirconia-containing frits into the glaze batch." The formula White Zircon Borax Frit is referred to as a zirconium silicate-opacified frit and is a component used in the formulation of ceramic glazes combined with pigments. According to Williamson (1991) [5], mostly zircon tonnages are used in ceramics industries, with almost one-third being used as opacifying agents in the making of glaze frits, mostly for tile and sanitary ware applications. As described by PotteryCrafts, a WZBF manufacturer, WZBF is a glazing material suitable for producing once- and twice-fired earthenware white glazes. The company also stated that this frit is guaranteed to produce very good stable-colored glazes when combined with glaze stains [6]. In this research project, WZBF manufactured by PotteryCrafts will be used in all glazing recipe tests. The following table (Table 1) shows WZBF's (Code: R1122) chemical composition.

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2. Test Clay—Local Earthenware Clay Recipe Description

All the glazing recipes composed in this project were applied on a locally-composed earthenware clay created by the Alanwar Ceramic Tiles Plant (ACTP). This type of earthenware clay is formed locally from six different raw ingredients 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% [7]. This clay recipe contained different types of sands and pure red clays gathered from several Omani regions. More specifically, the clay used in this project included general sand (14%), fired ceramics grog (10%), Wadi Ghul clay (18%), Mahadha clay (28%), Lawa sand (14%), and Al Hamra clay (16%) [8]. As is the case at all ceramic plants, the raw materials were first ground in huge ball mills

Table 1. The chemical composition of White Zircon Borax Frit (WZBF), code R1122 (PotteryCrafts, 2022).

SiO ₂	B ₂ O ₃	ZrO ₃	MgO	Al ₂ O ₃	Na ₂ O	K ₂ O	CaO	Li ₂ O
55.9%	13.5%	12.1%	0.7%	4.4%	6.1%	0.2%	6.0%	1.2%

and then mixed homogenously in the main (and largest) ball mill.

This clay was transferred to the Sultan Qaboos University Ceramic Laboratory (SQUCL) for testing and development for a use completely different from its intended one. Whereas originally the ACTP developed this recipe for ceramic tiles, the aim of this project was to use it for slip-casted pottery. Slip casting is a method used in forming pottery worldwide in which liquid clay is poured into a plaster (gypsum) mold to make ceramic pieces. Many pieces were made and fired at a bisque temperature (1000°C) to make them ready for the glazing tests.

3. Experimental Research: Laboratory Tests

In this project, the researcher proposed laboratory experiments as a productive methodological addition to the existing published data regarding the use of White Zircon Borax Frit. The laboratory experiments were conducted under highly controlled conditions (including glaze firing) in which accurate measurements could be taken for evaluating the created tests. All tests were conducted in a ceramics glazing laboratory, and they included several stages, as follows.

3.1. Stage 1: Developing Matte Glazes

In order to compare the performance of White Zircon Borax Frit, four tests were conducted with different glass-formers, including silica, flint, quartz, and potash feldspar. The percentage of White Zircon Borax Frit was 50% in each recipe, and the added colorant was 8 g in each recipe. The table below shows the four tests in stage 1 (**Table 2**).

In this stage, all glazed tiles were matured in a low temperature range (Cone 06/1000°C) in an oxidation firing environment by electric kiln. The graph below (**Figure 1**) shows the firing timeline (temperature and hours).

3.2. Stage 2: Developing Test 3 from Stage 1

According to the results extracted from stage 1, Test 3 (WZBF 50% and flint 50%) was selected for developing additional recipes with different colorant stains as showed in **Table 3**.

Table 2. Glazing tests in stage 1 of the laboratory experiments on WZBF frit.

Test No.	Recipe	%	Added Colorant
Test 1	Frit (WZBF)	50%	8 g
	Silica	50%	8 g
Test 2	Frit (WZBF)	50%	8 g
	Potash Feldspar	50%	8 g
Test 3	Frit (WZBF)	50%	8 g
	Flint	50%	8 g
Test 4	Frit (WZBF)	50%	8 g
	Quartz	50%	8 g

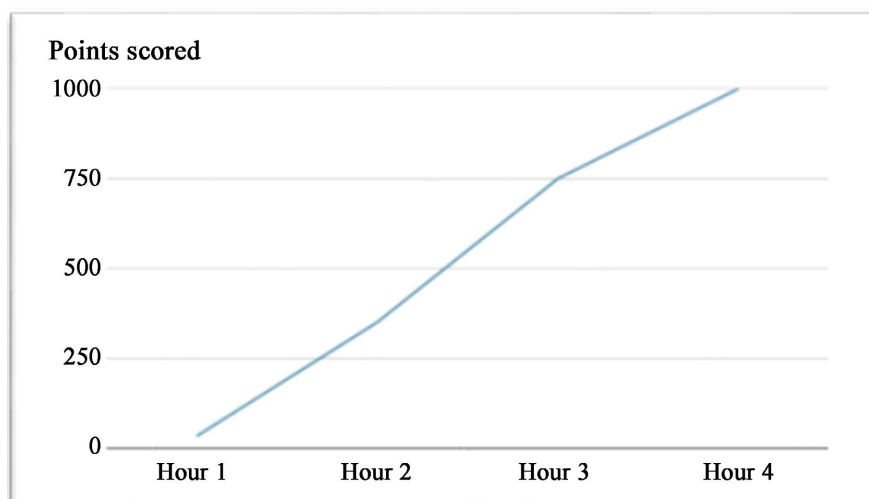


Figure 1. Firing timeline for testing the glaze recipe tiles in stage 1.

Table 3. Developing test 3 in stage 2 of the laboratory experiments by using Pottery crafts colorant stains.

Recipe 3	%	Added Colorant code and quantity (Pottery crafts Stains)
Frit (WZBF)	50%	Not Added, Test 5
		P4188.5 (8 g), Test 6
		P4182.5 (8 g), Test 7
		P4136.5 (8 g), Test 8
		P4185.5 (8 g), Test 9
Flint	50%	P4129.5 (8 g), Test 10
		P4108.5 (8 g), Test 11
		P4187.5 (8 g), Test 12
		P4148.5 (8 g), Test 13

In stage 2, all glazed tiles were also matured in a low temperature range (Cone 06/1000°C) in an oxidation firing environment by electric kiln, but about 10 minutes spacing time was added after temperature reaching 1000°C. The graph below (**Figure 2**) shows the firing timeline.

3.3. Stage 3: Reducing the WZBF Frit and Increasing the Quantity of Glass-Formers

The researcher followed the instructions given in stages 1 and 2 for making and applying the glazes. The quantity of WZBF frit was reduced to be less than the glass-formers, including flint, silica and potash feldspar. The three new recipes are given in **Table 4**, as follows.

In stage 3, all glazed tiles were matured in a high temperature range (Cone 8/1280°C) in an oxidation firing environment by electric kiln. The graph below

(Figure 3) shows the firing timeline.

3.4. Stage 4: Using WZBF Frit with Glass-Formers and Fluxes

The traditional method of blending glass-formers, stabilizers, and fluxes in each

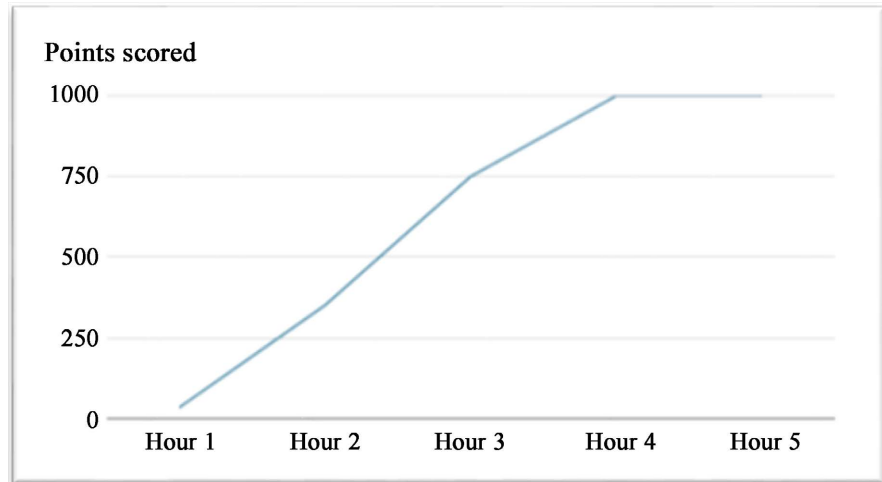


Figure 2. Firing timeline for testing glaze recipe tiles in stage 2.

Table 4. The recipes of stage 3 of developing glazing test tiles (reducing the WZBF frit and increasing the glass-formers).

Test No.	Recipe	%	Added Colorant
Test 14	Frit (WZBF)	20%	8 g
	Flint	80%	P4188.5
Test 15	Frit (WZBF)	10%	8 g
	Silica	90%	P4182.5
Test 16	Frit (WZBF)	20%	8 g
	Potash Feldspar	80%	P4136.5

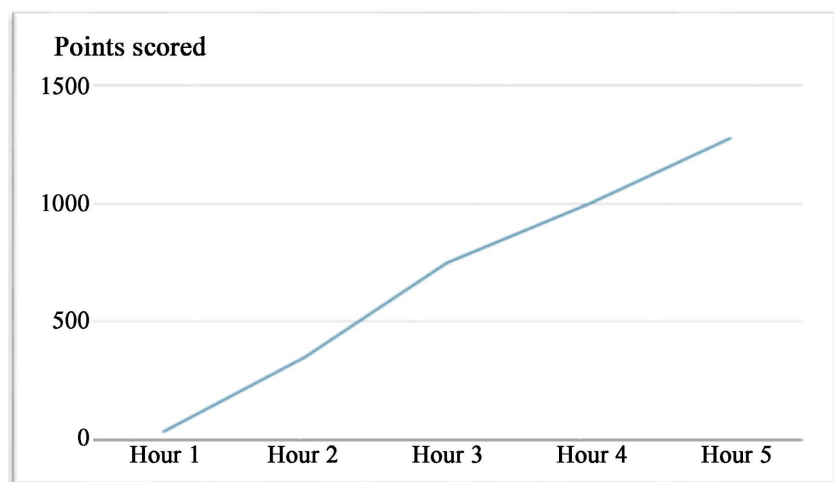


Figure 3. Firing timeline for testing glaze recipe tiles in stage 3. The highest proposed temperature was 1280 °C (Cone 8).

recipe was conducted in this stage of the lab experiments. Most of these materials are included in WZBF frit as a part of its composition (see **Table 1**). The following table (**Table 5**) describes three tests using the classical structure of glaze recipes, including glass-formers, stabilizers, and fluxes.

Similar to the firing range and timeline used in the stage 3 tests, all the glazed tiles in stage 4 were matured in a high temperature range (Cone 8/1280°C) in an oxidation firing environment by electric kiln. The diagram (**Figure 4**) below shows the firing timeline.

4. Results Review

Testing ceramic colors by composing glaze recipes is the most basic and probably the most important analytical tool in investigating the artistic visual decoration of ceramic pots. A large amount of visual information can be drawn from

Table 5. The recipes of stage 4 in which the classical method of composing glazes, including glass-formers, stabilizers, and fluxes, was applied.

Test No.	Recipe	%	Added Colorant
Test 17	Frit (WZBF)	20%	8 g P4129.5
	Flint	50%	
	Borax	30%	
Test 18	Frit (WZBF)	10%	8 g P4108.5
	Silica	50%	
	Talc	40%	
Test 19	Frit (WZBF)	20%	8 g P4187.5
	Potash Feldspar	50%	
	Bone Ash	30%	

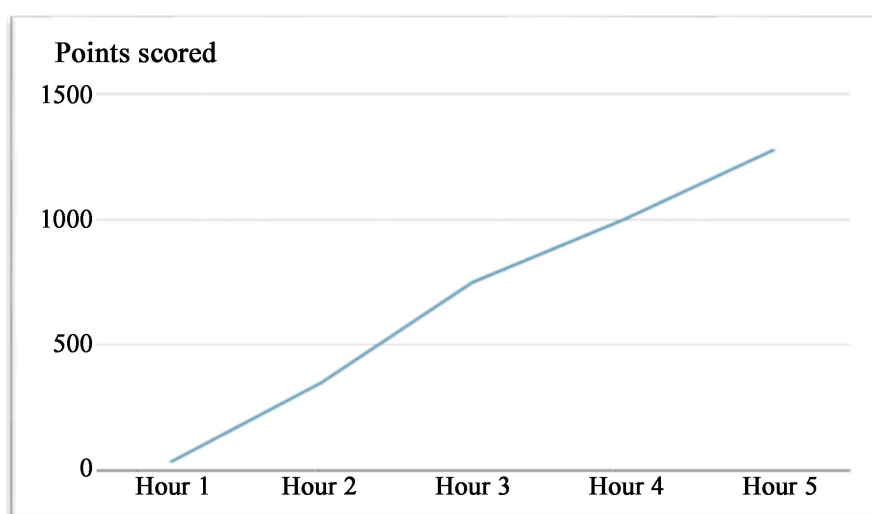


Figure 4. Firing timeline for testing glaze recipe tiles in stage 4. Similar to the firing range of stage 3, the proposed highest temperature was 1280°C (Cone 8).

Table 6. Analyses of the recipes, including the quality of fit with the selected local clay, appearance (matte/opaque), and glaze defects.

Test No.	Fitting for Clay	Matt	Opaque	Glaze Defects
1	✓	✓	✓	✓
2	✓	✓	✓	✓
3	✓	✓	✓	✓
4	✓	✓	✓	✓
5	✓	✓	✓	✓
6	✓	✓	✓	✓
7	✓	✓	✓	✓
8	✓	✓	✓	✓
9	✓	✓	✓	✓
10	✓	✓	✓	✓
11	✓	✓	✓	✓
12	✓	✓	✓	✓
13	✓	✓	✓	✓
14	✗	✓	✓	✗
15	✗	✓	✓	✗
16	✓	✗	✓	✓
17	✓	✓	✗	✓
18	✓	✓	✓	✓
19	✓	✗	✗	✓

this method of laboratory investigation, especially since several glazing recipes were created in this project. However, visual inspections must be carried out by trained and experienced ceramicists; otherwise, vital information may be lost which could adversely influence the findings of the investigation. Consequently, visual investigations were performed at the end of the experimentation stages, as shown above, in which 19 glaze recipe tests were extracted as tangible samples of colored ceramic tiles.

As can be seen in the test images shown in **Figure 1**, there are significant differences between the tests conducted in this research. Strong evidence of matte textures and suitability with Omani local clay was found for the majority of achieved recipes, but a few tests showed well-known glaze defects, such as crazing, shivering, crawling, pin holing, and blistering. **Table 6** provides a visual analysis of all 19 tests from a ceramics point of view, including their fit with the selected local clay, appearance (matte/opaque), and glaze defects. **Figure 5** showed



Figure 5. Images of the 19 test tiles of the project through all research stages.

all approved images of the 19 test tiles of the project through all research stages.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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