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Water Absorption Capacity and Visual Qualities of Pulverised Glass as a Component for Glass Ceramic Glazes

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Abstract

Defects of glass-ceramic-glazes have hindered their production and use in ceramic art practice. It was assumed that the defects are low water absorption induced. This paper consequently studied different types of glass for glaze production with the aim of examining their water absorption capacity, resistance to flow, dispersion behavior and visual qualities to determine suitable glass types for glaze derivation. Eight different types of glass, usually available as cullet in refuse dumps, were used. The samples were carefully cleaned, hammer-milled, pulverized, sieved using 350 nm fine mesh, subjected to dry-based water absorption test, elementally analysed through Particle Induce X-ray Emission technique and milled into four glaze batches. The batches were applied on two groups of 32 ceramic tiles with one group fired at 950°C and the other fired at 1100°C. Findings showed that the glass types are characteristically similar but with varying water absorption capacity from 22.5 to 32.5% and that the higher the water absorption capacity the better the melting and visual qualities of the glazes. Since usage of cullet will result in cleaner and safer environment, and glass-derived glazes comparatively melt at a low temperature with better visual qualities than other glaze types, its production should be developed using glass with high water absorption capacity.

1. Introduction

Powder or liquid glazes are usually mixed with water. Suspension of glaze particles in water is often determined by permeability tendency of the glaze recipes. Absorption coefficient of glaze particles in water is a measure of dispersion of recipes on biscuit wares at both application stage and after vitrification. Glaze suspension as slurry gives ceramic wares the hard vitreous strength, smooth touch and substrates chemical inertness after vitrification [1]. Glazes are formed from materials that consist of aluminum silicates of potassium, sodium and calcium [2]. Some of these materials incorporate crystalline matter in their formation [3]. Also, fritted glazes are prepared in a proportion of frit or pre-melted glass. Glass is a pre-melted material that is usually formulated in relation to glaze components, but it becomes cullet after post consumers' usage. Cullet therefore is a waste or scrap glass capable of being melted for reuse.

In composition, cullet is irregular atomic structure of higher percentage of siliceous dioxides capable of melting and cooling down for solidness [4]. It is poly-crystalline solid materials [5] which contained SiO_2 +

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Al_2O_3 + X while X = (CaO, Na_2O, MgO, TiO_2, PbO, FeO, ZnO, ZrO_2) [6] capable of viscousness after melting temperature.

Conversion of cullet to glaze recipes is chemically interesting on account of elemental oxide compatibility. However, cracks, crazes, crawls and pore formations are major defects of glass-ceramic-glazes. These problems have discouraged and limited production of glass-ceramic-glaze in Nigeria. The defects could be the result of low coefficient of water absorption. Also, poor ratio in glass-ceramic-glaze constituent could equally cause low dispersion of glass-ceramic-glaze on biscuit wares. Nonetheless, extraction of silica from cullet for glaze has a lot of energy saving in terms of melting temperature when combined with flux and alumina agent.

Some scholars have utilized several techniques in estimating water absorption coefficient of different materials while a few numbers of others have also worked on studio derivation of glass-ceramic-glaze. Some examples of those that worked on water absorption coefficient are [7] that determined absorption coefficient of water at 488 and 541.5 nm using a diabetic laser calorimetry. [8] used remote sensing reflectance from particulate to examine absorption coefficient volume of turbid water in average spectral distribution measured with and without polarization while [9] estimated water absorption coefficient of autoclave aerated concrete (AAC) using the Time Domina Reflectometry (TDR) method which is an electric method adapted for soil science.

In another study in this category, [10] examined water absorption coefficient and performance characteristic of bricks, glass and concrete powdered mixture as a substitution for building mixes. In the category of studio ceramic glass-glaze derivation, [11] studied physical and chemical analyses of different types of glass and produced glass ceramic glaze from their cullets, [12] converted cullet to glaze for ceramic artistic, economic and environmental development, and [13] centred on physical and chemical analyses of feldspar ceramic glazes produced with fluxes. Those studies on water absorption coefficient were not concerned with glass-ceramic-glaze while those on glass-ceramic-glaze derivation have not been concerned with water absorption coefficient. The techniques studied by the two categories of scholars nonetheless provide good information for the current study.

This study therefore is an investigation of different types of glass as materials for glass-ceramic-glaze production. The specific aim of the study is to examine the water absorption capacity, resistance to flow, dispersion behavior and the visual qualities of cullet-derived glazes with a view to determining suitable glass types for glaze derivation in ceramics studio practice.

2. Materials and methods

A total of eight (8) different types of glass classified as electric glass, soda lime glass, crystal glass and borosilicate glass [14,15,16,17,18,19] constitute the sample frame for this study. The glasses used are windowpanes, beverage glass bottles, perfume glass bottles, glass cups, alcoholic drink bottles, pharmaceutical bottles, cathode ray tube and auto-mobile glass. Cullets were collected from users, repairers, garbage cans, building construction sites and waste dumps. The samples were cleaned through washing with clean water and cleansing agent (detergent) that emulsified and extinguished unwanted materials, and heating at 120°C. They were thereafter hammer-milled with jar crusher based on glass and colour types to break them into small chips. The samples were pulverized using pulveriser machine (Rocklabs, model CRC 3E) and sieved to obtain nano or smallest particle size. The washed samples were poured and entangled in 350 nm fine mesh for five hours and were later sun-dried in a clean plastic tray. Details of final samples after drying are presented in Table 1.

The quantities and colours of the pulverised samples used in this study are as shown in Table 1. Also in the table were borax, potash, soda ash as fluxes and ball clay. Five grams (5g) of samples were accurately weighed into labeled glass beakers with initial alphabets of the glass types indicating their colours viz: PHB_g (Pharmaceutical Bottles $_{brown}$), GCP_w (Glass Cup $_{blue}$). Samples in the bakers were saturated with 20 ml distilled water. The cullet-water mixtures in the beakers were thoroughly stirred to make them homogeneous before the suspensions were filtered to determine outflow water volume and retained percentage. Each suspension was examined for six (6) hours until the running of water ceased. The volume of outflow water from each of the samples was quantified while the retained water and retained water percentage were calculated.

A measure of the rate of decrease in the volume of water as it passes through the pulverized glass particle and the fraction of water absorbed are determined in Table 2. The Table identifies dried samples (grams), distilled water (ml), saturated mixture, final outflow water volume (ml), retained water (ml) and retained water percentage (%) in simple percentage instrument of:

Where "a" is initial water volume (ml), "b" is volume of filtrate (ml), "c" is retained water volume (ml), the retained water percentage is given by

$$\frac{(a-b)\times 100}{a}$$

The samples weight and initial water volume (*IWV*) for the mixture varied differently in quantity. The volume of filtrate *(VOF)* changed and the changes were observed on the water retained by each sample suspended in filter papers. The volumes of filtrate differences were used to determine actual retained water volume (*RWV*). These were ascertained by subtracting initial water volume (*IWV*) from the volume of filtrate (*VOF*) (i.e., *IWV-VOF=RCV*). The percentages of retained water volume (*RWV %*) were also established by multiplying retained water volume (*RWV*) with hundred (100) divided by initial water volume (*IWV*). From the table, water retained by soda ash was zero and could be attributed to hygroscopic tendency and high solubility nature in water. The concentration of oxides in each sample was determined through Particle Induce X-ray Emission (PIXE). The essence of the three chemical materials of potash, soda ash and borax is to determine suitable flux for the batches and the constituents of each of the selected glass samples to the ratio of additive materials are presented in Table 3.

2.1 Cullet Glaze Application and Firing

The glazes were applied on the sixty-four (64) biscuit ceramic tiles produced in an art studio for the glazing exercise. All the tiles were drenched in water for 30 minutes and desiccated to permit the cullet-ceramic-glazes alignment and penetrability to the clay body.

Table 1: Pulverised Cullet, Chemical Additive and Ball Clay weight (in kg)

S/N	Glass types	Colour types	Weight (kg)
1.	Windowpane glass (WPG)	Transparent white	6.43
2.	Beverage glass bottles (BGB)	Transparent white	9.08
3.	Perfume glass bottles (PGB)	Blue	1.99
4.	Glass cups (GCP)	Blue	3.28
5.	Alcoholic drink bottles (ADB)	Brown	5.50
6.	Pharmaceutical bottles (PHB)	Brown	9.23
7.	Cathode ray tube (CRT)	Grayish Purple	3.94
8.	Auto-mobile glass (AMG)	Grayish-Purple	1.61
9.	Borax (BRX)	White	8.02
10.	Soda ash (SDH)	White	10.25
11.	Potash (PTH)	Cream white	10.67
12.	Ball clay (BCY)	Brownish gray	25.34

Table 2: Water Absorption/Retention Capacity Results

S/N	Glass types	Colour types	Saturated mixture (5g+ 20ml) (a)	Filtrate of volume (ml) (b)	Retained water (ml) (a-b)	% Retained water
1	Windowpane glass (WPG)	Transparent white	20	15.2	4.8	24.0
2	Beverage glass bottles (BGB)	Transparent white	20	14.3	5.7	28.5
3	Perfume glass bottles (PGB)	Blue	20	15.2	4.8	24.0
4	Glass cups (GCP)	Blue	20	14.9	5.1	25.5
5	Alcoholic drink bottles (ADB)	Brown	20	13.7	6.3	31.5
6	Pharmaceutical bottles (PHB)	Brown	20	15.2	4.8	24.0
7	Cathode ray tube (CRT)	Grayish-purple	20	15.2	4.8	24.0
8	Auto-mobile (AMG)	Grayish-purple	20	15.5	4.5	22.5
9	Borax (BRX)	White	20	17.2	2.8	14.0
10	Potash (PTH)	Milk white	20	15.2	4.8	24.0
11	Soda ash (SDH)	White	20	-	-	-
12	Ball clay (BCY)	Brownish gray	20	14.9	5.1	25.5

Thereafter, cullet-ceramic-glazes were applied on the biscuit ceramic tiles. Dipping method was adopted for the application after thorough shaking of each glaze composition. Cullet-ceramic-glaze applications were done in stages of the selected temperatures (950 and 1100°C) for the experiment. The tiles were differentiated into two groups with surface design: 32 smooth and 32 patterned.

Thirty-two (32) smooth surfaced biscuit tiles were selected for 950°C firing. The other (32) patterned surfaced biscuit tiles were selected for 1100°C firing to determine the suitable temperature for these cullet-ceramic-glaze compositions. The glazes were fired separately in two groups with a gas kiln powered with three burners at two different temperatures (950 and 1100°C).

3. Results and Discussion

The percentage of oxides in cullet, chemical fluxes and geological material are highlighted in Table 4.

The major oxides in the samples are Na_2O, MgO, Al_2O_3, SiO_2, CaO, TiO_2, PbO and FeO while P_2O_5, SO_3, K_2O, ZnO, ZrO_2, Sb_2O_5, Rb_2O_5, SrO and BaO are minor and below detection limit of the equipment used in this study. All the glaze batches containing soda ash cracked when dried. Perhaps, this was due to hygroscopic elements and absorbent nature of the material. The results in Tables 5 -12 comparatively show water absorption capacity effects and visual qualities of glass-ceramic-glaze recipes on biscuit wares. The tables revealed the kiln trial temperature results, mature surface quality of the colour

Table 3: Batch constituents of each glass sample in percentage

Sample Batch compositions	Batch 1	Batch 2	Batch 3	Batch 4
Pulverized sample	90	70	70	70
Ball clay	10	10	10	10
Borax	-	20	-	-
Soda ash	-	-	20	-
Potash	-	-	-	20
Total	100	100	100	100

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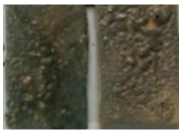
Table 4: Oxides Composition of Pulverised Cullet, Chemical Fluxes and Geological Samples

Structure Typologies	Colour types	Cullet Oxides Concentration (%)																		
		Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	FeO	ZnO	ZrO_2	MoO_3	Sb_2O_5	Rb_2O_5	SrO	BaO	PbO	Total
Window panes Glass	Clear white	13.85	3.24	0.18	76.51	0.06	0.34	-	5.55	0.02	0.09	-	0.01	-	0.12	-	-	-	-	100.00
Beverages Bottles	Clear white	12.31	1.29	0.36	78.24	0.08	-	-	6.90	0.63	0.17	0.01	0.02	-	-	-	-	-	0.03	100.00
Pharmaceu-tical Glass	Brown	13.58	0.86	0.36	77.16	0.08	-	0.52	6.77	0.11	0.35	0.01	0.09	-	-	0.02	0.07	0.02	0.01	100.00
Alcoholic bottles	Brown	12.93	0.45	0.35	77.75	0.11	-	0.55	7.17	0.09	0.32	0.01	0.04	0.02	0.21	0.01	0.04	0.00	0.01	100.00
Perfume bottles	Blue	13.26	1.34	0.44	77.20	0.11	-	-	6.91	0.09	0.08	0.01	0.04	-	-	0.01	0.02	0.05	0.44	100.00
Glass cups	Blue	15.06	0.85	0.47	76.97	0.11	-	-	6.03	0.02	0.04	-	0.02	0.02	-	-	0.01	0.40	0.01	100.00
Cathode Ray tube	Grayish purple	9.01	0.66	0.41	68.88	0.19	-	5.63	1.60	-	0.09	0.10	0.82	0.11	0.28	0.01	2.83	8.79	0.63	100.00
Automobile Glass	Grayish purple	9.83	1.36	0.33	73.51	0.06	0.15	3.97	2.27	0.06	0.07	0.01	0.04	0.05	-	-	0.25	7.93	0.12	100.00

	Colour	Chemical and Geological Materials Oxides Concentration (%)																		
	Colour	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	FeO	B_2O_3	ZrO_2	Cl	Sb_2O_5	Rb_2O_5	SrO	BaO	PbO	Total
Borax	White	32.33	0.22	0.14	1.82	0.02	0.24	-	0.43	-	0.04	64.65	0.04	-	-	-	0.03	-	-	100.00
Potash	Milk white	29.08	0.20	0.16	6.61	0.33	-	58.16	0.33	0.02	0.12	-	-	6.69	0.04	-	-	-	1.13	100.00
Soda ash	White	98.70	-	0.04	0.77	-	0.13	-	0.07	0.00	0.02	-	-	0.18	-	-	-	-	0.09	100.00
Ball clay	Brown-ish gray	1.06	1.48	6.04	81.47	0.18	-	1.74	0.49	0.53	6.45	0.01	0.09	-	0.42	0.03	0.03	-	-	100.00

Table 5: Visual results of windowpane glass (transparent colour) after kiln and firing

Batch Number			1	2	3	4
Visual results						
			Batch 1:$WPG_{tw}B$	Batch 2:$WPG_{tw}BB$	Batch 3:$WPG_{tw}SB$	Batch 4:$WPG_{tw}PB$
Recipe compositions			$WPG_{tw}B$	$WPG_{tw}BB$	$WPG_{tw}SB$	$WPG_{tw}PB$
Test wares			Tiles	Tiles	Tiles	Tiles
	1	950°C	Matt and cracked	Melted and glossy	Melted and bub-bled	Melted and glossy
	2	1100°C	Melted and glossy	Melted and crazed	Melted and crazed	Over-fired and burnt
Output colour			Transparent	Transparent	Transparent	Transparent
Matured surface quality			Glossy	Glossy	Glossy	Glossy
Composition evalua-tion			Good	Good	Fair	Good
Resistance to flow			Thick	Thick	Thick	Thick

resultant glazes resistant to flow of the glazes. In each of the plates are two (2) tiles containing results of the cullet-ceramic-glazes fired at 950 and 1100°C temperatures.

The visual results of transparent windowpane glass composition for glazes in table 5 appeared successful. Batch 1 with acronym $WPG_{tw}B$ was a composition from transparent white windowpane glass at ratio 90% glass and 10% ball clay. The composition matured at 1100°C and gave transparent white colour effect. The glass-ceramic-glaze result had underneath colour, perhaps the effects of the colour added to the glass composition. The compositions of batches 2, 3 and 4 dispersed effectively at 950°C. Chemical additives mixed with the three compositions invigorate their flow resistance in terms of thickness.

Stiffness and viscousness provided by ball clay as binder of Batch 1 appeared successful. The ball clay prevented run-off of glass-ceramic-glaze. Pore formations that appeared on the batches with soda ash and potash can be attributed to thermal stresses [11,12]. Uneven heat radiation in the kiln may equally crack and craze the compositions. Likewise, differences in heat pressure and uneven heat movement in kiln chamber at 550°C above could cause these defects.

$PGB_{bl}BB$ is highly susceptible to devitrification to the extent that no cracks or pore formations could be obtained. The borax en-

Table 6: Visual results of Beverages bottles (transparent colour) after kiln and firing

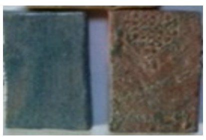
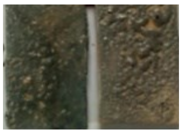
Batch Number			1	2	3	4
Visual results						
			Batch 1:BGBtwB	Batch 2:BGBtwBB	Batch 3:$BGB_{tw}SB$	Batch 4:$BGB_{tw}PB$
Recipe compositions			BGBtwB	BGBtwBB	$BGB_{tw}SB$	$BGB_{tw}PB$
Test wares			Tiles	Tiles	Tiles	Tiles
	1	950°C	Matt	Melted and glossy	Melted and bub-bled	Melted and glossy
	2	1100°C	Melted and glossy	Over-fired and burnt	Over-fired and burnt	Over-fired and burnt
Output colour			Translucent	Translucent	Translucent	Translucent
Matured surface quality			Glossy	Glossy	Glossy	Glossy
Composition evalua-tion			Good	Good	Fair	Good
Resistance to flow			Thin	Thin	Thick	Thick

Table 7: Visual results of Perfume Glass Bottles (blue colour) after kiln and firing

Batch Number			1	2	3	4
Visual results			 Batch 1:$PGB_{bl}B$	 Batch 2:$PGB_{bl}BB$	 Batch 3:$PGB_{bl}SB$	 Batch 4:$PGB_{bl}PB$
Recipe compositions			$PGB_{bl}B$	$PGB_{bl}BB$	$PGB_{bl}SB$	$PGB_{bl}PB$
Test wares			Tiles	Tiles	Tiles	Tiles
	1	950°C	Matt and cracked	Melted and bubbled	Matt and cracked	Melted and cracked
	2	1100°C	Melted and bubbled	Melted and glossy	Melted and bubbled	Melted and glossy
Output colour			Blue	Blue	Blue	Blue
Matured surface quality			Glossy	Glossy	Glossy	Glossy
Composition evaluation			Fair	Good	Fair	Good
Resistance to flow			Thick	Thick	Thick	Thick

sures proper dispersion of the composition and became blue crystalloid at 1100°C. This can be attributed to the role played by sodium and boron elements in borax which decreased silica melting temperature [4]. Also, the soda ash and potash in $PGB_{bl}SB$ and $PGB_{bl}PB$ respectively controlled the silica crystallization into favourable surface stability.

The results in Table 8 showed glass cups as composite material for glaze production. $GCP_{bl}B$ revealed the difference in the melting temperature of compositions mixed chemical additives. At 1100°C, $GCP_{bl}B$ had not attained maturation temperature. To obtain glossy and smooth surface texture, the composition requires 1200°C and above. However, the latter temperature may be reduced with the addition of more additive materials. For example, the three batches with chemical additives of borax, soda ash and potash gave quick responses to heat at 950°C in both melting and crystalloid effects.

The differences in the surface morphology of the batch compositions of alcoholic drink bottles are as shown in Table 9. The physical features showed differences in cracks and glossiness. The reactions of chemical additives to batches were also disparately distinct. The result of batches with borax and potash gave assurance that glass-ceramic-glaze can be made from dark brown alcoholic cullet at low temperature without cracks and

Table 8: Visual results of glass cup (Blue colour) after kiln and firing

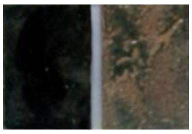
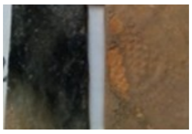
Batch Number			1	2	3	4
Visual results			 Batch 1:$GCP_{bl}B$	 Batch 2:$GCP_{bl}BB$	 Batch 3:$GCP_{bl}SB$	 Batch 4:$GCP_{bl}PB$
Recipe compositions			$GCP_{bl}B$	$GCP_{bl}BB$	$GCP_{bl}SB$	$GCP_{bl}PB$
Test wares			Tiles	Tiles	Tiles	Tiles
	1	950°C	Matt and pored	Melted and glossy	Melted and bubbled	Melted and glossy
	2	1100°C	Melted and cracked	Melted and cracked	Melted and cracked	Melted and cracked
Output colour			Blue	Blue	Blue	Blue
Matured surface quality			Glossy	Glossy	Glossy	Glossy
Composition evaluation			Fair	Good	Fair	Good
Resistance to flow			Thick	Thick	Thick	Thick

Table 9: Visual results of Alcoholic Drink Bottles (dark brown colour) after kiln and firing

Batch Number			1	2	3	4
Visual results			 Batch 1:$ADB_{db}B$	 Batch 2:$ADB_{db}BB$	 Batch 3:$ADB_{db}SB$	 Batch 4:$ADB_{db}PB$
Recipe compositions			$ADB_{db}B$	$ADB_{db}BB$	$ADB_{db}SB$	$ADB_{db}PB$
Test wares			Tiles	Tiles	Tiles	Tiles
	1	950°C	Matt and cracked	Melted and glossy	Matt and cracked	Melted and glossy
	2	1100°C	Matt	Overfired and burnt	Overfired and burnt	Overfired and burnt
Output colour			Brownish-green	Dark brown	Brownish-green	Brownish-gray
Matured surface quality			Opaque	Glossy	Opaque	Glossy
Composition evaluation			Fair	Good	Fair	Good
Resistance to flow			Thick	Thin	Thick	Thick

pores.

The visual results in Table 10 explain the composition of brown pharmaceutical bottles with ball clay and the reaction of chemical additive agents in formulating glass ceramic glaze. Melting temperatures of batches that contained borax, soda ash and potash are similar. All the cullet-ceramic-glazes with additive materials were over-fired and leached at 1100°C temperature. A direct opposite to Batches 2, 3 and 4 is found in Batch 1. The latter crystallized and matured at 1100°C.

Table 11 above presents visual results of glass glaze batches formulated with grayish-purple cathode ray tube. Batches 2, 3 and 4 with borax, soda ash and potash melted at 1100°C and this can be attributed to elements in the fluxes which contain more melting diminution of boron, sodium and potassium oxides. Pore formations on their surfaces may be the result of the thermal compatibility of the materials [13].

The results of the four batches appeared dusty and chalky at 950°C. Batches with borax and potash mixed were matt at 1100°C. Surface results of these two batches can be improved when subjected to a high thermal temperature of 1250°C and above. Other batches also have tendency of good surface quality if subjected to 1250°C and above with

Table 10: Visual results of pharmaceutical bottles (brown colour) after kiln and firing

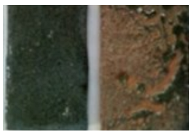
Batch Number			1	2	3	4
Visual results			 Batch 1:$PHB_{br}B$	 Batch 2:$PHB_{br}BB$	 Batch 3:$PHB_{br}SB$	 Batch 4:$PHB_{br}PB$
Recipe compositions			$PHB_{br}B$	$PHB_{br}BB$	$PHB_{br}SB$	$PHB_{br}PB$
Test wares			Tiles	Tiles	Tiles	Tiles
	1	950°C	Matt and cracked	Melted and glossy	Melted and crazed	Melted and crazed
	2	1100°C	Melted and glossy	Overfired and burnt	Overfired and burnt	Overfired and burnt
Output colour			Brown	Brown	Brown	Brown
Matured surface quality			Glossy	Glossy	Glossy	Glossy
Composition evaluation			Good	Good	Good	Good
Resistance to flow			Thick	Thick	Thick	Thick

Table 11: Visual results of Cathode Ray Tube (grayish purple colour) after kiln and firing

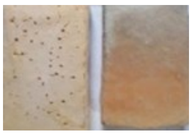
Batch Number			1	2	3	4
Visual results						
			Batch 1:$CRT_{gp}B$	Batch 2:$CRT_{gp}BB$	Batch 3:$CRT_{gp}SB$	Batch 4:$CRT_{gp}PB$
Recipe compositions			$CRT_{gp}B$	$CRT_{gp}BB$	$CRT_{gp}SB$	$CRT_{gp}PB$
Test wares			Tiles	Tiles	Tiles	Tiles
	1	950°C	Matt	Melted and pored	Melted and bubbled	Melted and bubbled
	2	1100°C	Melted and bubbled	Melted and glossy	Melted and pored	Melted and glossy
Output colour			Grayish-blue	Grayish-green	Grayish-blue	Grayish-green
Matured surface quality			Glossy	Glossy	Glossy	Glossy
Composition evaluation			Good	Good	Good	Good
Resistance to flow			Thick	Thick	Thick	Thick

trends of results from selected temperatures. The visual results of all the selected eight (8) glass types as glass-ceramic-glaze recipes on biscuit wares after firing were analyzed in the above tables. Different results were found after firing at the two selected kiln trial temperatures. Mature phases of some samples were 950°C while others melted at 1100°C and above.

4. Conclusion

In conclusion, the effects of water absorption coefficient of selected glass on each of the batches and physical features of all the glass glazes were evaluated. The method adopted for the analysis is differential drainage volume technique. The result from water absorption coefficient test and visual analysis results showed that samples with high retention capacity gave good dispersion effects on biscuit wares and matured at low temperature (950°C). The implication of the retention rate is affirmed in most of the batches from automobile glasses with high heat of stoneware temperature and low water absorption rate which could be attributed to high percentage of silicon in the sample. The surface characterizations of all glazes and the structural effects of borax, soda ash and potash on each batch at 950 and 1100°C proved cullet as ma-

Table 12: Visual results of Automobile Glass (grayish purple colour) after kiln and firing

Batch Number			1	2	3	4
Visual results						
			Batch 1:$AMG_{gp}B$	Batch 2:$AMG_{gp}BB$	Batch 3:$AMG_{gp}SB$	Batch 4:$AMG_{gp}PB$
Recipe compositions			$AMG_{gp}B$	$AMG_{gp}BB$	$AMG_{gp}SB$	$AMG_{gp}PB$
Test wares			Tiles	Tiles	Tiles	Tiles
	1	950°C	Underfired	Underfired	Underfired	Matt and peeled
	2	1100°C	Matt	Matt	Matt and pored	Matt and pored
Output colour			Chalky green	Chalky green	Chalky green	Burnt-sienna
Matured surface quality			Opaque	Opaque	Opaque	Opaque
Composition evaluation			Fair	Fair	Fair	Fair
Resistance to flow			Thick	Thick	Thick	Thick

terial for glass-ceramic-glazes. Significantly, this study has produced cullet-ceramic-glazes low, medium and high temperature ranges and in some ways, provided an avenue for utilization of glass waste and solution to solid waste disposal challenges for a better and safe environment. Since usage of cullet will result in cleaner and safer environment, and glass-derived glazes comparatively melt at a low temperature with better visual qualities than other glaze types, its production should be developed using glass with high water absorption capacity.

Conflict of interest
We have no conflicting interest with this research and the publication of the paper.

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