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The effect of using bentonite in the production of ceramic glaze (Crawling)

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Abstract

The current research deals with an experimental study in the Crawling Glaze technique under the low temperature range (980) degrees Celsius, where a local bentonite clay was used as a catalyst to achieve the effect of Crawling on the ceramic surface, and white clay (Akashat) was chosen as a body for the application by adding non-plastic materials such as silicic sand and grog, as well as kneading (burnishing) the ceramic surface to be ready for this technique, a homemade alkali glaze was used to achieve (crawling glaze) with aesthetic dimensions of artistic specificity in this experiment, and with these capabilities and local materials, the goal was achieved. Adding (18%) of bentonite to show the best results from the technical and aesthetic point of view, and the research has achieved results that were similar to the Crawling glaze in the other developed countries in the world.

Keywords: bentotite - ceramic glass - ceramic techniques - plastic art - fine arts.

Introduction

(Research Determinants)

The research problem: The art of ceramics is one of the arts that is based on scientific and artistic experience. The methods of formation, glazing and burning techniques differed and varied according to the nature of space and time and the need for it. And this art has become accepting intellectual and experimental transformations and revolutions in the system of shape, color, movement, size, space, and even the type of glaze used. In the past, the art of ceramics was based on disciplined hierarchical systems. Everything outside the context of the glazed surface, light weight, classic utensils, and transparent glaze is considered a mistake or outside the system of tradition and familiarity. The potter began a journey of searching for new technical concepts, whether in clay or glaze , according to a contemporary visual vision that is in line with the developments of the era and other visual arts. And after the tremendous scientific development and technical progress that the world witnessed in the middle of the twentieth century in particular, intellectual and cultural visions and concepts changed, as well as openness and modernization subjects leads to the concept of change and development in various fields of science, technology and the arts, so society became accepting everything that was new and unfamiliar, as a result, the potter began looking differently and reconsidering all the previous mistakes little by little through the treatments of glaze errors, which today have become techniques that fall within the concept of difference and which constitute a great shock to the recipient, such as (Crackle.glaze) and (Matt.glaze) and (Bubble.glaze) and (Crawling.glaze) which is the focus of our current research, and these techniques are known today as special glaze. This led to the emergence of new pillars that overthrew all the previous traditional concepts of ceramic art based on the data of transformation and change and not defined by the restrictions of the past. This constituted a contemporary strategy in the treatment of the ceramic surface, to announce the beginning of new technical concepts to control any fault of the glaze and make it a contemporary technique that has artistic and aesthetic connotations and dimensions that are renewed with the renewal of the era.

Through the foregoing, the researcher decided to put the following questions to the problem of her research:

1- What are the success factors of Crawling in ceramic glaze? What are the most important aids to it?

2- How and when is the effect of Crawling achieved in the ceramic glaze through physical and chemical factors?

Background

The importance of the research: The importance of the research lies in identifying the understanding and revealing the secrets of the Crawling technique in the ceramic glaze through a compatible process for the type of clay, glaze, and materials assisting in the Crawling , as well as the importance of knowledge with the appropriate thermal range, and this benefits students and researchers in the institutes and colleges of fine arts to understand all the details of it in ceramic glaze and the possibility of developing this type of glaze in the short or long term, The interest in the technical and experimental aspect is the most important aspect and the main axis of this art as well as being the real aspect of research and development..The current research is also a cognitive contribution in the field of visual by identifying a new technique among contemporary Iraqi ceramic techniques and with a purely local raw materials. The research also contributes in enriching the specialized library with a new experimental studies in presenting the concepts of Crawling technique in contemporary ceramic glaze.

The objective of the research

The current research aims to identify the extent of the effect of bentonite on showing the Crawling in the ceramic glaze.

The limits of the research:

1. White Clay (Akashat)
2. Non-plastic materials - (river sand - grog)
3. Glaze - Alkaline *
4. Materials that stimulate Crawling - (Bentonite) *
5. Temperature - 980 c

Literature Review

Definition of terms:

Effect: the effect...the impact on the thing (Al-Razi, 1983, p. 3) influenced it, left an impact on it (Ibrahim, 1972, p. 5) and the effect is the result of the thing and has several meanings:-(The first: means the result, which is the result of the thing, and the second: in the sense of the relationship, and the third in the sense of the feature denoting the thing.) The effect may be called on the thing that is actually achieved, as it is an accident from something else, and it is, in a sense, synonymous with the effect or the reason for the thing (Saliba, 1982, p. 37).

Effect (procedurally): It is a process in which a change occurs to matter, as a result of the interaction of two or more substances, provided that there is a catalyst for that effect by exposure to heat, so the components begin to interact to produce something new.

Bentonite : a type of clay of volcanic origin, containing a high percentage of silica ($Al_2O_3.4SiO_2.2H_2O$) with a difference in molecular structure from other clays, and has a high ion exchange ability (Al-Ajmawi, 1974, p. 234) Therefore, bentonite has the ability to absorb an amount nearly twice that of other clays, because it is characterized by its softness. The origin of naming bentonite clay by this name is attributed to the American city (Fort Benton), where this clay is found in large quantities (Al-Qaisi, 1989, p. 46).

Bentonite (procedurally): It is a clay that has characteristics that differ from the rest of the other types of clays because of its chemical formula and molecular structure, which do not contain a bond between them, and for this reason what gives bentonite a high shrinkage rate, which can be benefited from in our current research in the production of (Crawling glaze).

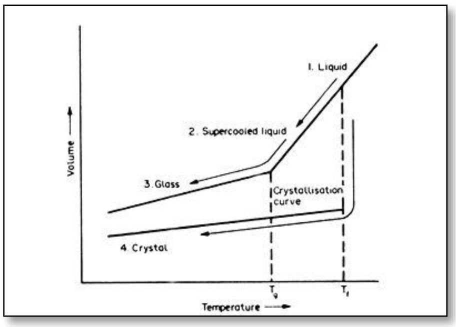
Crawling: occurs in the liquid state, and it has to do with surface tension, so a sudden change occurs in the viscosity dimensions of the material as a result of an influence, so the liquid turns into island-like clusters, as a result of a difference in the expansion coefficients between the material and the surface (https:// digitalfire.com/home/search/crawling).

Crawling (procedurally): is a phenomenon that occurs irregularly within the layer of glaze, so it leaves the ceramic body free of glaze, gathered in the form of small or large spots according to the type of glaze and the type of influencing material as well as the correct temperature, to reach the artistic and aesthetic impact of this phenomenon on the work.

(Theoretical Framework)

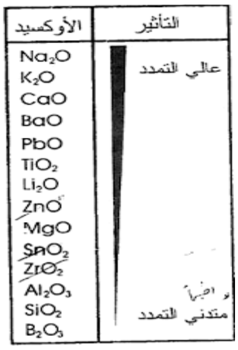
Nature of the Glaze

The ceramic glaze is a super coold liquid, forming a thin, solid layer that covers the pottery body and bonds with some of its compound elements. It consists of thermal fusion of silica compounds to cover the pottery surface, thus canceling its permeability and granting the property of preserving liquids, in addition to increasing its resistance to mechanical stress or melting with acids (Al-Badri, 2002, p. 41).



Glaze and its techniques play an important role in the manufacture of ceramic art, and there is a very important matter, which is (a transition point between the two states and the liquid-solid in which the viscosity increases with the increase in temperature. It is impossible to classify the glaze as liquid or solid, as the transition from solid to liquid depends on the strength of the bond, the stronger the bond, the higher the temperature ((Al-Hindawi, p. 16), In this case, when the cooling range is short (short rang), it moves to the glazey solid state, but if the cooling range is slow (long rang), this leads to the crystalline state (Taylor.1986.p2) as in Figure (1) which shows the transition from liquid state (1) with rapid cooling (2) the glazyy state (3) .. but in the case (4) (slow cooling) the glaze moves to the crystalline state (Taylor. 1986, p3).

Glaze Fitness:



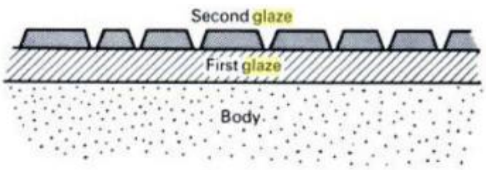
The congruence and overlap between the glaze layer and the ceramic body is of great importance in the production of ceramic work. The congruence of the glaze is the suitability and harmony of the glaze layer with the earthenware body after thermal settlement. One of the properties associated with this process is (thermal expansion and contraction) that each of the glaze and the pottery body has its own thermal expansion rate according to the composition of its components, so the glaze tends to expand and contract at a specific rate that differs from the pottery body in terms of volume change rates as a result of thermal expansion and contraction, which requires Knowing the appropriate thermal ranges for the pottery body and the glaze (Hamer.2004.P. 147-148). Among the common errors as a result of the non-conformity of the glaze to the pottery surface that occurs during firing or after a period of time is a partial Crawling of the glaze layer from some parts of the ceramic work surface, which sometimes reaches peeling and complete fall of the glaze layer if accompanied by a weakness in the bonds of the two surfaces as a result of the difference in the coefficients of expansion and contraction between the layer of glaze and the ceramic body after thermal settlement, so if the shrinkage of the ceramic body after cooling is much higher than that of the glaze layer, a lot of pressure will occur on the glaze, which will produce what is known as flaking (shivering). But if the shrinkage of the glazes is greater than the shrinkage of the ceramic body, it leads to the occurrence of cracks and fine hair fractures known as Crazing (Taylor.1986.P.79). Accordingly, almost all materials with heat shrink and shrink by the same amount when cooling, so if the expansion coefficient is high, then the shrinkage will be high and vice versa, and each material has an expansion coefficient that differs from the other as in Table (1), Therefore, the potter must know, study, and understand the materials and compounds that enter into the composition of clay and glaze, as well as knowledge of the material expansion coefficient in order to overcome the errors of variation in the rate of contraction of both the glaze and the pottery body (Hamer.1975.p147).

Crawling glazes

Crawling is the collection of molten glaze in the form of lumps resembling (islands), leaving bare spots free of glaze in the pottery body and with thick edges. The crawling is either simple and there are only a few spots free of glaze, and sometimes it is severe so that the glaze takes the form of drops or beads (Michael.2003.p120), and this texture aroused the interest of potters to employ it in ceramic sculpture, as in Figure (2), and from the foregoing it is clear that crawling is a layer of glaze that shrinks away from the surface of the pottery during firing. It could be a result of a very thick layer of glaze, or rapid firing that causes separation of the glaze shell as a result of the exit of water vapor present in the working pores, which works to raise the glaze and not stick to the ceramic body (Muller 2011. P310). (it also occurs in the glaze when the glaze does not fit with the pottery body, forming a fault in the glaze, so the glaze crawling away from the surface of the clay during firing and often forms holes or beads in the surface of the glaze, revealing the surface of the pottery body. This can happen due to the dust on the work surface or the oil stains or by means of thick paint (Burleson, 2003, P38) (It is the tendency of the glaze to raise itself off the surface of the vessel and to gather in granules or drops. It is likely that the ceramic body was dusty or greasy before the glaze, which prevented the adhesion of the vitreous liquid to the surface of the pottery during the glaze. There is a high percentage of clay in the composition of the glaze (Rogers. 2003. p 87). The glaze must be viscous enough to retain the carbon dioxide gas bubbles resulting from the silicon carbide added to the glaze. It often occurs in Shino glaze) because it contains a very high percentage of clay, which shrinks upon drying and forms a cracks (Linda.2020.p120). Some potters use two layers of glaze, the first layer is burned at a low temperature to a degree without damaging the absorption property, then it is coated with a second layer of glaze that contains a high clay level of 20% or 30%, which causes the second layer to shrink. When the smelting process is completed, the second layer cracks, forming a series of floating pieces in the first layer. And it appears as if it is a retractable glaze, as in Figure (3) (Frank and Janet Hamer.p217). The occurrence of crawling is due to the failure of the glaze layer to adhere properly to the pottery body during the fusion process due to the weakness of the bond between the glaze surface and the pottery body (Henrik, 1999, p26). The phenomenon of crawling in the glaze has aroused the interest of the contemporary potter, so they are looking for how to employ this line aesthetically as a contemporary technique.

Types of crawling :

1- The crawling that occurs when applying the glaze to the pottery body if it is applied excessively or to increase the oxides that stimulate the shrinkage of the glaze in more than usual proportions (Emmanuel.2004.p36)



2- crawling that occurs when applying a layer of glaze over a layer of glaze that burns at a temperature without losing the absorption property, and it occurs in the second layer (Frank and Janet Hamer.p217)

3- The crawling that occurs when applying glaze to unburned clay bodies (Fraser.1998.65)

Materials used in the research:

Bentonite: a soft-grained, pale-coloured, ductile clay that is formed by the chemical transformation of volcanic ash and is mainly composed of montmorillonite, and its properties depend to a large extent on the ion exchange property (s.e.shahad.2003.p51).

It is a secondary clay formed from volcanic ash instead of igneous rocks. The main component of bentonite is montmorillonite. Bentonite swells noticeably when mixed with water. Bentonite also forms very smooth colloidal gels, even at low concentrations. It causes very severe drying, which causes an increase in contraction during burning(Jamis.2008.p121), which are clays with high shrinkage and absorb about three to five times their volume of water, so they are not suitable for use alone in shaping pottery pots, as they crack during drying or burning and cooling, so they are added at a rate of 2-6% to the ceramic body to improve plasticity (Al-Zamzami. 1996. p. 142).

Indicators of the theoretical framework:

1. It is preferred that the clay body be very smooth, rubbed to reach a super softness.

2. The dust or fat on the ceramic surface may lead to a crawling in the glaze.

3. The high percentage of alumina in the ceramic glaze has the ability to crawl on the ceramic surface.

4. It is preferable to apply the glaze to the surface in a proportion more than usual, to reach (2 mm) to achieve the best crawling in the ceramic glaze.

5. Of the crawling factors in the ceramic glaze are the oxides and compounds that help, and accurately determine the proportions of their addition to the glaze mixture.

6. Rapid burning may lead to retraction in the glaze layer.

Materials and methodology

Chapter Three (Research Procedures)

Research procedures: In this chapter, the researcher reviews the scientific, applied and laboratory procedures through which the research objectives are achieved.

The research methodology: Since the research aims at the effect of (crawling) in the ceramic glaze and its artistic and aesthetic effect on the ceramic surface, the researcher relied on the experimental approach as the most appropriate approach to achieve the goal of the research in an accurate scientific way, as an approach based on the scientific experiment that reveals the causal relationships and the factors influencing them (Al-Zubaie, 1981, p. 87).

Chemical analysis: A chemical analysis of the materials included in the research was carried out in the Iraqi Geological Survey and Mining Authority to know the materials and compounds used in the research, in order to identify the components of the materials included in the current research.

Pottery models experiments: After conducting a number of preliminary experiments, this model was chosen from clay that bears the correct specifications for the success of the technique in ceramic glaze, see the following table.

Kaolin	Grog	Flint
08	10	10

This model was chosen after the surface was treated by means of (Burnishing) process. The smoother the surface, the greater the chance of the glaze crawling on the surface, as it cannot cling and adhesion due to the absence of pores on the surface.

Clay preparation: After selecting the suitable clay mixture for the research through the previous experiments carried out by the researcher, the clay preparation process was carried out using the traditional plastic method.

Formation of models: After preparing the clay, then the process of forming models is completed by spreading the clay in the form of sheets with a thickness of (1 cm) and cut according to the required area into models measuring (8 cm x 6 cm x 1 cm).

Drying the models: After the process of cutting the clay models, they are left to dry slowly, so they are covered with a cloth for a period of (24) hours. After that, they are placed one on top of the other to ensure that no curvature occurs in the models for a period of three or five days until they are completely dry.

Burning models: Clay models were burned in the College of Fine Arts / University of Baghdad in an oven measuring (40 x 30 x 35), where a number of preliminary experiments were conducted on burning clay models to find out the appropriate burning temperature that is compatible with the data of the current research, and temperatures were chosen (1150 °C) based on the success of the experiments at this temperature according to the program in the following table, with the temperature fixed (Soaking) for one hour to give the samples time to reach the (hardening state), after that it was slowly cooled according to the cooling program.

Burning time	Temperature
50°c/h	0°C _ 300°C
75°c/h	300°C _ 600°C
100°c/h	600°C_ 1000°C

After reaching the required temperature, thermal stabilization (Soaking) was adopted for half an hour, after which cooling took place, and its readings were recorded according to the following table:

Cooling rate	Temperature
70°C/h	800°C_1000°C
60°C/h	550°C_800°C
50°C/h	50°C_550°C

Crawling Glaze Experiments

The researcher conducted a series of preliminary experiments in order to reach successful results in the production of (Crawling) glaze at a temperature of (980 °C) as follows:

No.	Alkaline glaze%	bentonite	Total
1	98	2	100
2	96	4	100
3	94	6	100
4	92	8	100
5	90	10	100
6	88	12	100
7	86	14	100
8	82	18	100
9	80	20	100
10	75	25	100
11	70	30	100

After completing the initial experiments, it was found that paragraph (8) in the above table is the best result in terms of crawling .

Preparing the glaze mixtures: After completing the initial experiments and choosing the appropriate model, the glaze mixtures were prepared depending on the percentages constituting the mixture and using weight of the dry matter. The method of work also included mixing the raw materials well, then adding water gradually with continuous stirring until the mixture became slip then the filtering process was done with a sieve (120 mesh) using a brush to push the mixture through the holes to get a plankton-free mixture.

The application of glaze on pottery models: The process of applying the mixtures of the glaze on the pottery models was carried out using the method of brush painting and pouring. A wide and small brush was used because this method gives the potter full control over the application of the glaze more than the other methods of application, as it gives an increase and density in the thickness of the glaze layer After conducting a number of preliminary experiments, it was found that the best thickness for the production of retractable glaze applied to pottery bodies is (2 mm).

Burning and cooling program:

Burning program: After completing the process of applying the glaze to the pottery models, the pottery models are placed in the oven and burned before the glaze layer dries well because this process helps the glaze to crawl, and the presence of moisture causes crawling in the glaze layer, and the oxidizing condition continues until the temperature is reached the full, as indicated in the following table.

Burning time	Temperature
40°c /h	Room temperature _200°c
80°c/h	200°c _ 600°c
100°c /h	600°c _980°c

This type of burning is called the normal programmed (Firing Converting), which depends on timings to raise the temperature. The reason for choosing this type of burning is that the length of increasing the burning leads to the melting of all glaze compounds (Cooper, 1978, p.116). The source is not fixed in the list.

The process of cooling the glazed models: After the furnace reached the required temperature, the furnace was slowly cooled from (980 C - 700 C) after all the furnace outlets were closed. This stage is before the glaze hardens and from (700 C - air temperature) the time period was faster because the glaze became solid according to the following table:

Temperature	Cooling rate
°C _700°C	60°c /h
700°C _ normal weather	80°c /h

After completing the requirements of the current research, a number of scientific and laboratory tests were conducted, including the chemical analysis of the materials included in the composition of the models, as well as the examination of hardness and scratching.

Results and discussions

(Research Results).

Chemical analysis of materials included in Crawling Glaze

Chemical analysis results:

Total	**L.O.I**	**K_2O**	**Na_2O**	**TiO_2**	**MgO**	**CaO**	**Fe_2O_3**	**AL_2O_3**	**SiO_2**	Oxides / materials
99.99	11.16	0.07	0.27	1.12	2.51	3.26	0.23	31.65	49.72	Kaolin
98.96 5	0.22	0.02	0.03	0.11	0.028	0.086	0.061	0.33	98.08	river sand

99.98	**10.75**	**1.21**	**1.07**	**1.7**	**2.27**	**1.12**	**9.15**	**26.15**	**46.56**	grog
99.9	4.02	2.78	9.13	-	2.21	4.68	2.22	11.42	63.44	Alkaline glaze
99.54	9.05	0.76	2.04	0.22	2.22	0.77	2.09	14.23	57.03	bentonite

The results of the external appearance and color of the pottery model:

The burnt sample at a temperature of (1000 °C) was characterized by a flat external appearance without warping or curvature. The white color appeared with a few brown dots due to the impurities present in the clay composition of non-plastic materials, as in Figure (4).

Hardness test results

The results of the hardness test were shown according to the Vickers scale, as shown in the following table:

Samples	Examination readings			read rate
	1	2	3	
2%	74	72	76	74
4%	74	73	77	75
6%	73	74	78	75
8%	47	76	78	76
10%	78	73	79	77
12%	78	73	79	77
14%	77	77	80	78
16%	81	80	79	80
18%	82	86	84	84
20%	85	86	84	85
25%	88	87	86	87
30%	89	88	87	88

The results of the scratch test:

The results of the scratch resistance test for the glaze surface showed the (Moh's Scale of Hardness) system, as shown in the following table:

Model no.	Resist testing
1	2% 7.5
2	4% 7.6
3	6% 7.8
4	8% 7.9
5	10% 8
6	12% 8
7	14% 8.1
8	16% 8.3
9	18% 8.3
10	20% 8.4
11	25% 8.5
12	30% 8.5

Conclusions:

1. One of the factors for the success of crawling is the process of matching the type of slurry with the type of glaze, as well as the type of additive that helps the crawling , as well as the correct application with the appropriate temperature that can achieve.

2. The bentonite gave the property of crawling to the ceramic glaze, as the bentonite is one of the materials with high surface tension, as it causes stress within a layer if it is added in the correct proportion to show the best crawling .

3. The crawling depends on physical factors, the most important of which are dust and fats on the pottery surface, as well as the thickness of the applied glaze layer, in addition to the glaze surface that rubs well.

4. As for the chemical agents, there are also factors for the success of the crawling in the ceramic glaze, such as the addition of materials and oxides that stimulate the crawling, as well as rapid burning or application with two different layers of glaze, and each type has a different melting point, and the burning is at one degree, then crawling is achieved.

5. Glaze that contains a high percentage of molten alkali oxides with a coefficient of thermal expansion has a high contraction rate upon cooling, such as sodium and potassium oxides.

6. There have appeared variations in the methods of employing the retractable glaze on the ceramic surface, some of which depend on the color of the glaze, and some that depend on the color of the clay.

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