



An experimental study to develop Pate de verre technique for reforming the glass powder thermally by using adhesives

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Key Words:

Pate de verre – Adhesives – Natural adhesive – Artificial adhesive

Introduction:

The glass powder fusing technique known by the term Pate de verre, is a very old technique returns to the first millennium BC, the ancient Egyptians used it in their amulets and inlays, after that it rediscovered in the era of Art Nouveau in the late of 1800's by Henry Cross, this term could translate literally of the French language to be "bonded glass" where glass sculptures made of glass powder (Kervin & Fenton, 2000).

This technology used to make solid or hollow sculptural products using molds, with many minute details and diversity of large chromatic massive. The traditional method of this technique depends on making sculptural models of multiple materials are usually of wax, then making thermal molds on those models, which are then used to fuse the glass powder.

This technique with the traditional methods needs lot of materials, tools, and high skills to make the sculptural glass product with high aesthetic and technology, specially adhesives thus the **research problem** is in the following questions: What is the best types of natural and industrial adhesives that are suitable for pasting appeared and the cohesion of the glass powder grains before and during the fire? , Is there any changes in the color, shape and size of the glass powder and its ability to shape freely without molds or with using assistant molds? What are the best types of adhesives that help in the formation of the glass powder constituted free without using a mold or with using assistant molds? **The research aims** to determine the relationship and technical effects of the adhesives in reforming the glass powder thermally, **the importance of research** in the development of re-forming the glass powder thermally technique using different adhesives. **The research is supposed** that by using different types of natural and industrial adhesives in paste glass powder grains can be developed the technical methods in the possibility of forming a powder constituted free without the use of molds or using the assistant molds.

Glass powder fusing depends on some main factors as:

- 1- Glass type (chemical composition – physical properties).
- 2- Glass thermal system.
- 3- The glass powder.
- 4- Adhesives.

1- Glass type:

The choice of glass type is the first important choices, because it depends upon the mainly processes of formation before firing, as well as determine the necessary thermal curve to fuse the glass, and compatibility with all the raw materials used, especially when using more than one color of glass must then be from the same glass type in order to avoid stress during firing.

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Glass as a material chemically composed of a mixture of metal oxides mainly of silicon dioxide SiO_2 and this known as silica glass or quartz, composed of molecules and atoms have within the formation of irregular crystalline, there are many different chemical composition of glass types, there are such as quartz glass is made by melting pure silica at about 1800°C , molten glass here has a high viscosity and is characterized by force and very high resistance, soda lime glass which alkali added to silica in the form of metal oxides, and lead glass which formed by adding lead to silica in small amounts, where a large amount affixed cause in the case of lead atoms instead of the silica atoms in the retina of glass due to the larger size of the lead than silica atoms, it characterized by low-melting point and its magnificent visual properties.

2- Glass thermal system:

For a successful glass powder fusing it must know the relationship between the physical properties of glass and heat, when changing the temperature of the glass powder each glass grain edges begins to rise its temperature and expands in size and volume, this according to the change that occurs in the retina of glass which occurs less in glass viscosity, The increase of those in the movement of glass atoms retina allow any stress exists within the glass which called Strain Point, therefore if the heating was quick at that point it is possible to break the glass and has a thermal shock, at this point also be the annealing point which is about 540 Celsius degrees.

By continuing raising the glass temperature over this point to reach all fusing stages , the glass grains begin in softening according to the gravitation which known as softening point from about 760 – 815 Celsius degrees, where the atoms movement raise quickly with no strain and glass grains become tack fusing and the full fusing. (Kervin & Fenton, 2000).

3- The glass powder:

The glass powder or what is known as frit is turned glass from large pieces to small grains by crushing. It is necessary to crush glass well before mixing with adhesives, where it is assets in the glass powder fusing technology not to see the glass powder large grains after the fusing process, the more the grains in small sizes, the better in the melting process because it reduces the size of air gaps between the grains, therefore less stress in the glass product, the size of these air gaps reduce on the other hand the process of sliding glass powder grains within the fusing molds. it also prefer to use more of sizes of the glass powder grains because it helps more in the process of fusing and reduces stress during firing. (Lundstrom, 1989).

Glass sculptures produced from the fine powder which looks like a flour seems in its appearance in an opaque finish such as porcelain, not glass, while the other which looks like sugar its final appearance is semitransparent, therefore the larger the size of the glass grains the more in glass transparency and the air bubbles which trapped between the glass grains (Kervin & Fenton, 2000).

4- Adhesives:

Adhesive as a term known as a common compound that can be used to assembly the materials to each other superficially. This term has expanded to include different materials such as mortar, glue, plants gum, starch and paste sticker, but adhered is the term used generally to denote a body which connects to another by the adhesive. It is possible that the paste operation also called bonding, this is a generic term that carries the meaning of other terms are used in some industrial fields such as gluing and cementing.



Classification of adhesives:

Adhesives are classified according to several types as the chemical composition which is of two types: (1) **Natural adhesives:** such as starch, dextrin, plant gum and proteins from plants and animals, animal bones, skins of fish and soybean flour, and there are also other natural materials such as asphalt and shellac, natural rubber, sodium silicate, oxy-magnesium chloride and the other organic materials.

(2) **Artificial adhesive:** such as Flexithrix resins by heat including esters cellulose, esters alkyd, acrylic, and multi-amide, a multi-styrene, synthetic rubber, multi-vinyl alcohol and its derivatives, resins hardened by heat, such as urea, melamine and phenol, and epoxy and finally polyhedra Aster unsaturated.

The most important glass adhesives:

- 1- Glues:** Glues are chemical compounds with high molecular weight gain mainstay gelatinous when exposed to moisture, and the solid mainstay when dry, some of which is a natural source and polyhedra skaredat, and derivatives manufactured chemically like tend cellulose, some of which is a synthetic made from low vehicles molecular weight, such as a multi (poly) vinyl chloride and multi-acrylic amide.
- 2- The Glue:** The glue of the oldest adhesives used for connecting non-metallic solids and paste it without affecting the specifications and properties. The core portion of the adhesive material with a high molecular weight compounds (multiple reducing polymer) or of the individual compounds (mono monomer met) and attributed to the properties of these polymeric compounds.
- 3- Silicone:** Silicon polymer is a semi-organic with a high molecular weight is made up of long chains of atoms of silicon and chlorine or oxygen, its first discovery was Frederick Stanley in England 1906, and silicon products are made in industry by interactions addition of olefins or interactions condensation the presence of sodium.
- 4- Epoxy Resin:** It is a chemical substance which considered one of solid thermoplastic elastomers with two components: the resin and the hardener which is highly resistant to adhesion and friction, chemicals whether acids or bases or solvents, where formed an insulating layer when dry. Used as paint or mortar or adhesive. The first attempt of production of this substance was in 1927 in the United States via the Swiss company Ciba of chemicals production.

The experimental study:

The experimental study mainly focused on adhesives to determine their effect on the glass powder in (cohesion - the ability to forming in assistant molds or freely - maintaining the shape, size and color of the glass during fusing process) .So the axes of the experimental study identified on three basic experiments: -

- 1- The effect of the glass powder grains sizes on its usability of forming freely or in assistant molds.
- 2- The effect of using the natural adhesives on forming the glass powder.
- 3- The effect of using the artificial adhesives on forming the glass powder.

As it has been the use of estimates (very weak - weak - good - very good - excellent) to discuss the results of experiments to determine the effect level of the adhesive on the glass powder grains.



1- The effect of the glass powder grains sizes on its usability of forming freely or in assistant molds.

The aim: Determine the effect of glass powder grains sizes on the capability of its formation freely or in the assistant molds.

Steps of the experiment:

- Mixing samples of the glass powder with grains size (2 mm -1 mm) (Fine) and another (less than 1 mm) (Powder) with constant of the water percentage (the simplest types of adhesives), type and color of the glass (blue glass COE 96).
- Pressing the mixture into the assistant mold of rubber silicon, then freezes at a temperature - 3° C for an hour to ensure the quality of the cohesion of the grains.
- Glass removed from the assistant mold and placed on the kiln shelf, then fired at a slow rate until 760 ° C degree.

Results and discussions:

- The best sample is no (2) (at least in the grains size) in terms of susceptibility to the formation freely and in the assistant mold.
- The smaller the grains size increased the cohesion and ease of formation as well as keeping the shape and size.
- Large the grains sizes make the glass keeps its transparency, color, and easy fusing.








2- The effect of using the natural adhesives on forming the glass powder:

The aim: Determine the effect of natural adhesives on glass powder grains cohesion, the capability of its formation freely or in the assistant molds and on the fusing process.

Steps of the experiment:

- Mixing samples of the glass powder with grains size (less than 1 mm) (Powder) with constant of the natural adhesives percentage (water – flour – starch – Arabic gum).
- Forming part of this mixture freely and the other Pressed into an assistant mold of rubber silicon, then freezes at a temperature -3° C for an hour to ensure the quality of the cohesion of the grains.
- Glass removed from the assistant mold and placed on the kiln shelf, then fired at a slow rate until 760 ° C degree.

Table (1) the results of experiment (2), sample (6 and 7)

Sample no	(6)		(7)	
Adhesive	Starch		Arabic gum	
	Before firing	After firing	Before firing	After firing
The sample				
				



Formation in assistant mold	Good	-	Excellent	-
Free formation	weak	-	Very good	-
Coherence between the grains	good	weak	Excellent	Very good
Keeping the shape	weak	Very weak	good	good
Keeping the volume	weak	Very weak	Very good	Very good
Keeping the color degree	weak	weak	Very good	Very good
Results and Discussion	- Starch makes glass powder elastically fluid. - Hard to keep the glass powder which mixed with starch the mold shape or the shape of the free forming for a long time because of the fluidity of the mixture. - Starch has a major influence on the glass color degree due to the adhesive conglomerate on the surface of the grains. - Starch has a direct effect on the cohesion of the grains after the firing and makes the glass brittle breaking easy.		- Arabic Gum makes the glass powder like the rubber paste. - Changed slightly the cohesion and shape of the glass mixed with the Arabic gum. - Arabic Gum is characterized by maintaining the degree of the glass color and purity of and firing from vapors and deposits on the glass surface. - Arabic Gum affect the shrinking size of the glass powder by about 5%.	

3- The effect of using the artificial adhesives on forming the glass powder:

The aim: Determine the effect of the artificial adhesives on glass powder grains cohesion, the capability of its formation freely or in the assistant molds and on the fusing process.







Steps of the experiment:

- Mixing samples of the glass powder with grains sizes (less than 1 mm) (Powder) with constant of the artificial adhesives percentage (Glue –White Glue –pate de verr glue –Fuse master glue –Glastac glue – Epoxy –Silicon).



- Forming part of this mixture freely and the other Pressed into an assistant mold of rubber silicon, then freezes at a temperature -3° C for an hour to ensure the quality of the cohesion of the grains.
- Glass removed from the assistant mold and placed on the kiln shelf, then fired at a slow rate until 760° C degree.

Table (2) the results of experiment (3), sample (12, 13 and 14)

Sample no	(12)		(13)		(14)	
Adhesive	Glastac Glue ³		Epoxy ²		Silicon	
The sample	Before firing	After firing	Before firing	After firing	Before firing	After firing
						
Formation in assistant mold	Very good	-	Excellent	-	good	-
Free formation	weak	-	Very good	-	good	-
Coherence between the grains	good	good	Very good	Very good	good	Excellent
Keeping the shape	Very good	Very good	Very good	Very good	good	good
Keeping the volume	Very good	good	Very good	Excellent	Very good	جيد جدا
Keeping the color degree	weak	Weak	Very good	good	good	good
	- The glue makes the glass powder mixture		- Epoxy resin makes the mixture of glass powder		- Silicone adhesive makes the mixture of	

² Epoxy resin is a high transparency, quick drying after mixing in five minutes.

³ Kind of industrial gums (liquid) which mainly consists of methanolic cellulose product by the US Bullseye Glass Company to paste the glass grains and burns at about 100 degrees Celsius.



<p>Results and Discussion</p>	<p>flexible and with low viscosity which facilitates the process of formation in the assistant mold and freely in the horizontal direction on the glass surfaces, but on the other side difficult in freely formation sculpture.</p> <ul style="list-style-type: none"> - A significant effect on the degree of the glass color. 	<p>a sticky paste which facilitates the process of formation in the assistant mold, and in three dimensional sculptural products, while the difficulty of formation in the horizontal direction for a long time as a result of the short time intransigence.</p> <ul style="list-style-type: none"> - It helps to keep the glass product the shape and size, with changing somewhat in the color degree. - Out odors during the firing. 	<p>glass powder with medium viscosity which facilitates the process of formation in the assistant mold, and in three dimensional sculptural products.</p> <ul style="list-style-type: none"> - It helps to keep the glass product the shape and size, with changing somewhat in the color degree. - Out odors during the firing.
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After the results of the experimental study of the technological methods innovative in the glass powder fusing, which take advantage from the effect of different adhesives to make variety of formations of glass powder which are not produced by traditional fusing methods, so it was possible to produce many of outstanding applications which added aesthetically and technically innovative effects as the following: -

Application (1)

The aim:

Emphasis on the possibility of freely forming the glass powder in the horizontal direction with a vicious decorative forms using water and Arabic gum adhesive.

The steps:

- Mixing yellow and red glass powder of grains sizes (less than 1 mm) (Powder) with water, and mixing blue glass powder of grains sizes (less than 1 mm) (Powder) with Arabic gum.
- Putting design on the thermal paper on the kiln shelf.
- Using the tools paint and settled the glass powder mixture on the decorative shapes and still the powder which not wanted by the coloring brush.
- The shelf placed inside the kiln and leave until the overall drought, then firing the glass at a slow rate until 760 ° C degree.



The first application



Application (3)

The aim:

Emphasis on the advantages of Epoxy adhesive in freely forming of the glass powder in three dimensional sculptural products.

The steps:

- Mixing yellow and red glass powder of the grains sizes (less than 1 mm) with Epoxy.
- Making some paste blocks of each color of glass powder mixed with epoxy, and are forming freely until the structure of the form is complete.
- Firing the glass at a slow rate until 760 ° C degree.



The third application

The research results and discussions:

- Using different adhesives can get out from the traditional ways of the glass powder fusing, from making models and molds to the possibility of the freely formation or using assistance molds.
- Water and Arabic gum are the purest and best natural adhesives, in terms of maintaining the degrees of color, size and shape of the glass product, with the purity of fire from odors and fumes or leave residue on the glass surface.
- The features a water and Arabic gum effect on the glass powder in its ability of the freely formation in the horizontal direction, but their use is difficult to form a glass powder freely to sculptural forms without resorting to an assistant mold.
- Using the features of water and Arabic gum adhesives can make minutes and vicious decorative forms with variety heights, without the need of traditional use of the complex technology in using glass saw for cutting such these decorative shapes.
- Flour feature as a natural adhesive effective on making the elastic paste of glass powder facilitates the formation to sculptures forms, and although its effect as an adhesive to maintain the glass shape, but it shrinks after the firing caused to change the degree of glass color and leave some residue on the glass surface.
- Using flour as an adhesive can make figurative sculptural glass powder with thin thickness, and vicious from the inside using assistant molds, without the need of making complicated molds from more than one part, as in the traditional ways.
- Epoxy is one of the best artificial adhesives in the cohesion of the glass powder and keeping the color degree, shape and size, with easily glass freely formation to figurative sculpture, but with defects in viscous and shortness of its formation time with out with odors during the firing.

References:

- 1- Biron, M. (2007). *Thermoplastics and thermoplastic Composites* (1st ed.). Elsevier.
- 2- Kervin, J., & Fenton, D. (2000). *Pate de verre and kiln casting of glass*. CA: Glass Wear Studios.
- 3- Koob.S.P. (2006). *Conservation and Care of Glass Objects*. London: Archetype publications Ltd.
- 4- Lundstrom, B. (1989). *Glass Casting and Mold making*. Canada: Vitreous Publications.
- 5- Wasel, M. (2005). *Polymers chemistry*. Elfager for Publishing and Distribution.