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Increasing Local Materials Contribution in Egyptian Ceramic Tile Industry

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ABSTRACT

Thisresearch encourages the use of Egyptian raw materials in Vitrified Stoneware Ceramic tiles industry, substituting imported materials.Egyptian Porcelain Stoneware tile industry imports more than 75% of its raw materials, which has a direct impact on Egyptian ceramic tiles final product cost compared to the imported ones.

The objectivesarereducing imported raw materials in manufacturing stoneware tiles body, and Studying the properties of some Egyptian materials to reach an optimized body composition meeting the international standard specifications. Study included materialsasball clay, Sinai kaolin, quartz and fluxes (especially Sodium feldspar) - Sodium feldspar forms more than 40% of the body composition of the Egyptian porcelain stoneware tiles- in order to define the best result, research followed the experimental &analytical method.

Paper keywords*: Fluxes, Sodium Feldspar (Albite), Stoneware Tile, Vitrification.*

1. INTRODUCTION

Up until the mid-1980s, Egypt depended entirely on imports for its ceramic products (tiles and sanitary ware). Since then local production has grown rapidly, largely through the proliferation of new private companies which have gained substantial market shares.Today the market is dominated by about ten companies and total production amounts to about 62 million square meters (50 million in 2000), domestic production covers about 85% of ceramic tile demand in Egypt (totaling about 43 million square meters).

The rapid increase in international consumption of Vitrifiedstoneware ceramictiles hasboosted the production of vitrified tiles in recent years; it has also resulted in increasing the efforts done to keep up with this growing consumption.

The development of the production processes and ceramic body composition led to continuous improvements in the final productfeatures; it can even be compared with the natural stone; providing it with improved properties such as mechanical strength,frost resistance, corrosion & abrasion resistance,…etc.

Thevitrified stoneware tiles production has largely increasedin Egypt, but it faces many obstacles in competing against imported products in terms of price.

Therefore, it is possible to reach an industrially produced stoneware ceramic tiles by controlling of body compositions and using Egyptian raw materials to act as fluxes maintaining same specifications of imported products.

2. Components of stoneware ceramic body

The natural raw materials used in the production of ceramic bodies consist of minerals that are rarely pure -mostly mixed with other materials-,yet not all properties arefound in one raw material to form a body composition with low water absorption rate, high mechanical strength, and appropriate features. Thus; composing the body is a vital stage in ceramic production process (by combining materials in specific ratios).We can have required featuresand it is possible to alter the features of the final product by developing a suitable mixture of raw materials.

2.1 Clays

Claysmay seem dry, but in fact they include more than 20% of water molecules retained around the crystal structure which gives the clays their most essential properties; plasticity and workability.Clayshave a high ability to easily absorb water and conserve it around their crystal structure creating bonds. Bonds created during water absorption allows clay to preserve their forms when completely dry. Clays also are characterized with mechanical green strength inthe drying stage, the range of this mechanical strength depends on the size of the minerals particles. The Three most common types of clays found in raw materials used in ceramic tiles industry are: kaolin, elite and chlorite[1].

Clays used in manufacturing stoneware tiles must be characterized with the following features:

- Light color.
- Rheological properties that obtain the required liquidity.
- Fusibility to provide suitable density during firing.
- Mechanical strength during and after firing.

Kaolin is used in the tiles industry on a large scale, due to its high melting point and white color after firing, which make it very appropriate for this industry (especially white porcelain stoneware tiles). Absence of iron, alkalis or earth alkalis impuritiesin the kaolin composition improves the properties required in the ceramic industry[2].

Most Egyptian types of kaolinreflects less white after firing than pure kaolin, as the aluminum oxide ratio in Egyptian Kaolin can reach up to 34-35 %.

Therefore, it can be concluded that due to the impurities that exist in the clay;whether in their natural composition or as a result of their extraction from mines; are the reason behind using with limited quantities in the composition of stoneware tile body(commercially known as porcelain tiles), because it decreases its vitrification degree or change its color into darker shades, thus it is hard to reach a white shade that enables coloring the tile body.

The clays used in vitrified stoneware tiles body can reach50% of the body composition, the Egyptian Kaolin can be used within 10% of the stoneware tile body (20% Egyptian Kaolin – 80% Imported Clays), so that it wouldn't affect its vitrificationdegree or color.

2.2Quartz

Quartz is a non-plasticraw material that is added to the tile body composition as a filling material, and also to control the properties of the product such asshrinking, thermalexpansion and porosity; it is a key component in vitrified stoneware tiles manufacture.

Quartz is the main source of silica that is added to the body to modifyits thermal expansion between body and glaze. White sand- developed from sand stone- is a pure source of Silica as well which is available in Red Sea Zone(Egypt) that is used in tile industry.

In general, Egyptian quartz is used in manufacturing the tile body of Stoneware tiles due to its purity with ratios between 8% - 10%; as it is one of the purest material in the world.

2.3 Feldspar

Feldspars decrease the maturity temperature of the tile body; thus are called fluxes; because of their weak ionic bonds that decreases the melting temperature, as these bonds are not of the same strength in all directions, they are the weakest in the direction where alkali atoms exist, which explains why it is easy to grind and melt feldspars[3].

Feldspar as a flux contains alkali oxides that form the matrix of the ceramic body, these alkali oxides provide a lower melting degree of the body composition, because they form the liquid phase, this is the role of the feldspar as a flux, in addition to developing the product porosity which is a key factor in minimizing the cost in the industry[4].Feldspars belong to aluminum silicate group;they differ according to the alkali oxide.

All different types of feldspars play a main role as a raw material in tile production, especially vitrified stoneware tiles, as these minerals increase bodyvitrification during the firing process;they increase the mechanical strength, and decrease water absorption ratio, which is the main feature of stoneware ceramic tiles.

Feldspars block the open pores and decrease the closed ones, by producing the liquid phase before reaching a high firing temperature.The quantity and viscosity of theliquid phase must be sufficient in order to increase filling of the pores in the body, it also improves the interaction between materials, so that sintering starts in low temperature followed by the vitrification stage, the distinct feature of feldspars is its high fusion, thus; its ability to integrate with other non-plastics materials which achievesvitrification in relatively low temperatures.

The main element in the fusion process is the alkali content of the feldspar, which is sodium oxide Na_2O and potassium oxide K_2O,that exist in the feldspar with ratios of 16.9% and 11.8% respectively, the closer to the theoretical values of the alkali content in the feldspar are, the greater its economic value is. They are mostly used in tile industry; especially sodium feldspar which is used in the production of stoneware tiles.

The different types of imported feldspars are generally used in the production of ceramic tile body in Egypt, as it helps reaching the required vitrification degrees without affecting color of the body, besides they are properly prepared, through pre-mining processes such as grinding and purification, to become ready to be directly used in tile body composition.

The Egyptian feldspars in Sinai -specifically sodium types- haven't yet been properly utilized in the tile industry despite their high purity level due to the lack of preparation industries which follow the mining process.

2.4 Talc

Talc is a soft-textured mineral which belongs to the silica group, its chemical composition is magnesiumsilicate $3Mg_3Si_4O_6$, or water magnesium silicate $3MgO.4SiO_2$ .H2O.

It is ranked the first according to Mohs hardness of (1.0), it contains impurities such as carbon or iron, but the most common are calcium oxide (up to 8%), aluminum oxide (up to 6%) and iron oxide Fe_2O_3 or FeO (up to 2%).Talc is used in the tiles industry as a flux due to the existence of magnesium oxide with a ratio of 32%, while its ratio in dolomite is only 21%, making talc a stronger flux.Talc is used in small ratios (2 - 6%) in the composition of vitrified stoneware tile body to strengthen the effect of feldspar as fluxes.

Using small ratios of talc in vitrified Stoneware ceramic tiles results in many benefits:

- Staining resistance (more than 1.6%).
- Improving the modulus of rupture with a ratio up to 30%.
- Improves the polishing process when the porosity of the body is very low.

- Decrease thermal expansioncoefficient.
- Increase the whiteness of the body whereas zirconium exists [5].

The various types Egyptian Talc are used in the tile industry with different levels of purity, the main impurity is mica.

3. EGYPTIAN MATERIALS WHICH WERE CHOSEN FOR THE PRACTICAL EXPERIMENT

The experiment aims to use Egyptian Local materials to obtain a vitrified stoneware ceramic tile body such as: Egyptian kaolin (Sinai kaolin), fluxes (sodium feldspar) and quartz,in order to reach the required properties in the samples of stoneware ceramic tiles;with regards to vitrification degree, water absorption ratio and modulus of rupture. We have to choose the suitable raw material and preparation stageof the body to achieve the objectives of the study.

Below is a descriptionof the materials used in the applied aspect and their specifications:

3.1 Sinai kaolin (Abu-Zenima)

The kaolin layers in Abu-Zenima area exists within thick layers of sand stone, the thickness which can be economically utilized ranges between 1-4.5 meters, while the thickness of the sand stone layers that enclose them ranges between 10-20 meters.The reserve balance of kaolin clayin north and south of Abu-Zenima is approximately 16.5 million tons.

3.2 Glass sand from Al-Zaafaranah (Quartz)

White sand or glass sand is a very pure type of silica sand which is characterized with its lowest content of iron oxide. It is used in manufacturing all types of glass. White sand in Egypt is located in Al-Zaafarah - Red Sea and Abu Zenima-South Sinai, among other places.

The white sand in Egypt is consideredone of the purest silica sourcesthat can be found in nature, as the silica oxide ratio is higher than 99.8%.

3.3 Sodium feldspar from Sinai

There are large amounts of Sodium feldspar in Al-tur valley -40 km north of SharmElsheikh-it is one of the most important materials which are directly used in ceramicsmanufacturing. Studies show that there are confirmed reserves of this material in terms of quality and quantity (approximately 26 million tons, and a possible reserve of 200 million tons, geological evidences indicate that the primary reserve reaches 1.5 million tons) [6].

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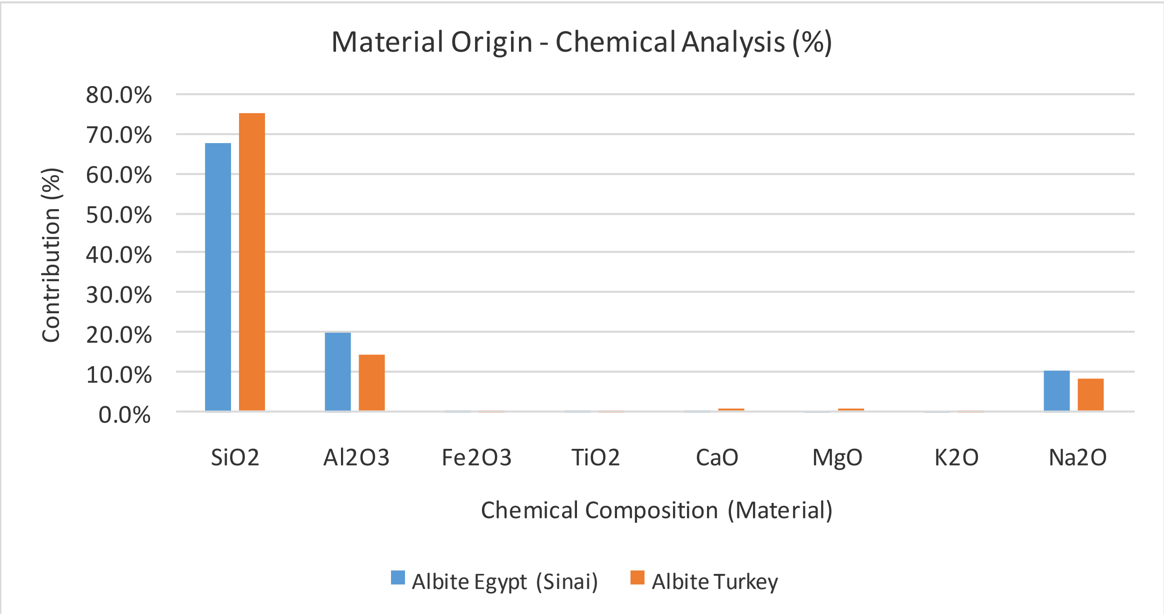
4. Chemical Analysis Comparison of Egyptian Feldspar and Imported One

Table (1) shows the chemical analysis of one of the Sodium feldspar samples extracted from the Sinai compared with Imported feldspar from Turkey used in one of leading Ceramic tile factories in Egypt.

The results show the ratio of iron impurities in Egyptian albite is 0.30% higher than the imported one. As for manganese the impurity ratio in Egyptian albite is about 0.40% lower, while sodium is 2% higher in Egyptian albite. Thus, the comparison demonstrates a close ratios of impurities, furthermore; the local albite has a higher ratio of sodium; so it can be used as a substitute for the imported materials without affecting the vitrificationdegree or color of the tile body.

Table (1) shows percentage of chemical analysis of a specimen of Feldspar from Sinai, Egypt and another Feldspar from Turkey

Material Origin	SiO2	Al2O3	Fe2O3	TiO2	CaO	MgO	K2O	Na2O
Albite Egypt (Sinai)	67.39	20.22	0.52	0.45	0.27	0.02	0.01	10.63
Albite Turkey	75.20	14.40	0.19	0.14	0.45	0.46	0.37	8.08



Graph (1) shows a comparison between the chemical analysis of a specimen of EgyptianAlbite and Turkish Albite

5. APPLIED ASPECT

Table (2)Shows chemical analysis of Egyptian and imported materials used in the experiment

Chemical Analysis																		
ELEMENT OXIDE (%)																		
Material Name	Chemical Composition	SiO2	AL2O3	Fe2O3	CaO	Na2O	K2O	P2O3	P2O5	MgO	MnO	TiO	TiO2	SO3	NO3	CL	L.O.I	TOTAL
Ball Clay-Aswan	ALUM. SILICATE	54.32	26.08	6.36	0.14		0.33		0.14	0.01	0.04	1.52		0.2		0.05	10.08	99.27
Turkish Clay	ALUM. SILICATE	64.12	22.65	1.01	0.5	0.33	1.85	0.14		0.7			1.29	0.11		0.02	7.27	99.99
Kaolin SAINAI-Abo Zinima	Al2O3.2SiO2.2H2O	63.57	22.57	1.08	0.83	0.05	0.15	0.1		0.29			2.21	0.12		0.04	8.87	99.88
Orthoclase SINAI	K2O.Al2O3.6SiO2	73.72	13.64	1.49	0.76	4.18	4.64		0.06	0.01	0.03	0.23		0.06		0.12	0.95	99.89
Alpite/Millitery Serv. SINAI	Na2O.Al2O3.6SiO2	67.02	18.44	1.11	0.97	9.77	0.33		0.33	0.17	0.01	0.39		0.08	0.1	0.06	1.03	99.81
Silica Sand/ Zaafarana	SiO2	94.92	2.2	0.12	0.69	0.04	0.03	0.01		0.27			0.11	0.08		0.04	1.45	99.96
White Talc	Mg SiO4	50.21	5.46	9.77	4.98		0.11		0.01	21.21	0.19	0.17		0.05		0.05	7.75	99.96

5.1Acomposition for stoneware ceramic tile body using Egyptian feldspar

The objective of the experiment is to use Egyptian materials; especially Sodium Feldspar (albite); in the composition to decrease water absorption to reach 0%, in order to increase the vitrification degree of the body and to achieve the international standards (ISO 13006) for this type of tiles.

Applied aspect body composition utilized Egyptian materials (Egyptian Albite, Kaolin and Glass Sand) with a ratio of 65% and Imported materials with a ratioof 35% (imported clay). While as per Industrial Norm in Egypt, Stoneware tiles production consume more than 75% of its composition of imported materials (Turkish Clay, and Sodium Feldspar) compared to 25% Local material (Kaolin, Talc and Glass sand).

5.2Operational Conditions

Grinding time: 60 min., pressing strength: 115 bar, firing temperature: 1220/1220 °C, firing time: 85 min.

5.3Proposed Composition

Table (3) Shows the proposed sample composition for vitrified stoneware ceramic tile (commercially know as porcelain):

Materials	Sample A
TurkishClay	35
Sinai Kaolin	9.50
Glass Sand (Al-Zafaranah)	9.50
Sodium Feldspar	44
White talc	2

Table (4) Shows the pre-firing test results (liquidity – density – residue)

Sample no.	Liquidity (second)	Density (gm/cm³)	Residue (gm)
(A)	16	1.68	0.0015

Table (5) Shows the post-firing test results (Linear shrinking ratio – Modulus of rupture – Water absorption ratio)

Sample no.	Linear shrinking ratio (%)	Modulus of Rupture (newton/mm²)	Water absorption ratio (%)
(A)	7.42	46.60	0

5.4The result of the applied aspect

The results of the experiment demonstrate that using local sodium feldspar has achieved 0% water absorption, 46.6 newton/mm²Modulus of Ruptureand theratio of linear shrinking is 7.42%, thus; achieving a stoneware ceramic tile body (commercially know as porcelain) that meets the international standard specifications (ISO 13006).

Sample (A) for Vitrified Stoneware Ceramic tile body

6. CONCLUSION

The study shows that various Egyptian martials can be used as a substitute for the imported ones inStoneware vitrified tile industry, obtaining specifications that meet the international standard (ISO 13006), with water absorption ratio of 0%.Applied aspect body composition utilized Egyptian materials (Egyptian Albite, Kaolin and Glass Sand) with a ratio of 65% and Imported materials with a ratio of 35% (imported clay). While as per Industrial Norm in Egypt, Stoneware tiles production consume more than 75% of its composition of imported materials (Turkish Clay, and Sodium Feldspar) compared to 25% Local material (Kaolin, Talc and Glass sand).

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