RHEOLOGICAL BEHAVIOUR OF A PORCELAIN SUSPENSION CONTAINING MAGHNIA BENTONITE

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ABSTRACT

The present work focuses mainly on the use of bentonite of Maghnia which is calcium type and is mixed with other clay materials for use in the construction of traditional porcelains. This study considers the properties of four mixtures with proportions of 0 to 15wt. % of bentonite. The rheological results of the mixtures obtained are rich in plastics components and this increases the rheological parameters namely the viscosity, the density, the residue on sieve of 0.063µm diameter, pH and the thixotropy.

At high viscosity appears rigidity that led to low shrinkage minimizing cracks from appearing of the layer paste deposited on the mold in a limited time, these variations are strongly related to electrolytes which ensure basic pH (9.73) of the medium, the hydrophilic behavior, and to the phenomenon of swelling of the bentonite clay. Finally, this study has shown that 10%wt. % mixture uploading of bentonite ensures good results rheological adequate for traditional porcelains.

Key words: *Traditional Ceramics, Rheological Properties, Calcium Bentonite, Hard Porcelain.*

NOMENCLATURE

Symbols :
T temperature, K
Wt. weight, %
V Viscosity, Cp
D Density, g/cm^3
t Time, s
A^0 Angstrom

Indices / Exponents :
0 standard formulation
1 formulation number 1
2 formulation number 2
3 formulation number 3

1. INTRODUCTION

Formulations of triaxial porcelain usually involve 25wt. % of plastic component, 25wt. % silica and 50 wt. % feldspar (generally sodium feldspar) for soft porcelain and 50wt. % of clay, 25wt. % silica and 25wt. % feldspar (generally potassium feldspar) for hard porcelain [1]. Bentonite is a natural mixture of minerals, it is characterized by a high capacity adsorption, ion exchange and swelling. There are two types of bentonite sodic and calcic. In order to realize the sodium bentonites, the calcic bentonites are treated by sodium hydroxide. They have the highest capacity of swelling. Bentonite is used extensively in various branches of industry (the paper, food, pharmaceutical and petrochemical industries, etc.) [2].

The obtained results by [3], [4], [1] of the use of the bentonite in the different formulations of ceramic pastes for wall tiles, bricks, ceramic tiles and porcelain stoneware are: processes during firing are different from those of the classical formulation of kaolin. Better control of the dimensional characteristics of pieces during firing has been achieved. Technological parameters pieces formulated with bentonite (shrinkage, modulus of rupture, apparent density, water absorption, expansion by humidity) satisfy the industrial requirements for the production of wall tiles and they have an important function: to confer plasticity in the green state and, during firing, undergo some structural modifications which furnish the main oxides to form some important phases such as mullite ($3Al_2O_3 \cdot 2SiO_2$).

The obtained porcelain tiles mixtures represent the plastic components that affect the rheological behavior .i.e. that increase the viscosity and the thixotropy. The held exchangeable cations on the layers surface were linked together. The intensity of these bonds depends on the valence of the cations [5]. More compensating cations are small and weakly charged, more the clay swelling is important. Therefore, in my study the bentonite swelling is low because of the exchangeable cations are Ca^{+2}. As a result, the specific surface is low. The reactive surface of bentonite clays takes the form of lateral faulted bonds and external basal-plane boundaries with a very low negative charge. For minerals of the kaolinite group the reactive surface is represented only by the edge regions of the crystals at the rupture sites on the bonds Si-O-Si and OH-Al^{IV}-OH when the fringe atoms of oxygen or hydroxyl are incompletely sutured with silicon and aluminum respectively. The aim of my study is to provide the performance of the nature of interactions between raw materials and calcic bentonite for producing the material porcelain tableware. According to the previous, the resulted materials using the calcic bentonite are not enameled. In this study several rheological parameters were studied including: viscosity, density, residue on sieve, pH and thixotropy.

2. EXPERIMENTAL METHODS

The different formulations of porcelain tableware (0, 5, 10 and 15wt. % of bentonite) were composed of kaolin from Djebel Debbagh, Guelma (Algeria) used in formulations tableware. The quartz comes from the area of Boussaâda (Algeria), the Feldspar from the area Bouira (Algeria) and the bentonite was calcined in a continuous roller kiln (heating to 973°K with a heating rate of $5°Ks^{-1}$ and maintained at this temperature for 3min). To this is added a sodium tripoliphosphate ($Na_2P_3O_{10}$, $6H_2O$) as deflocculant (0.3wt. %) to improve the dispersion of the slurries. Wide-angle X-ray spectra were recorded with a D 500 diffractometer (Philips PW 1710, France) in step scan mode using Ni-filtered CuKa radiation (1.5406 Å) . Elementary chemical analysis of raw materials were performed by ICP (Induced Coupled Plasma) references Iris, is marketed by Thermo jorrell (Cheshire, England). The rheological parameters such as the viscosity of suspensions, pH and thixotropy were determined by the following devices: a type viscometer (Model DV Brook Field III) and pH meter. The standard composition of triaxial porcelain, defined as P_0, was the formulation reference. Three formulations, with increasing amounts of bentonite (with respect to P_0), designated from P_1 to P_3 (the number refers to the wt. % of bentonite in the batch), were produced in laboratory conditions via pouring and sintering. Table 1 summarizes the batch formulations and the chemical compositions of the porcelains (in wt. %), Table 2 shows the chemical analyses of the raw materials. Bentonite was used in the three batch replacing feldspar that is normally used in traditional compositions. The main observations show the role of the bentonite as a fluxing agent.

Raw materials	Mass percentages (wt. %) P_0	P_1	P_2	P_3
Kaolin	55	55	55	55
Feldspar	25	20	15	10
Quartz	20	20	20	20
Bentonite	0	5	10	15

TABLE 1 . Formulations (in wt. %) of the model porcelain P_0, P_1, P_2 and P_3

Oxides (wt. %) / Materials	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	K_2O	Na_2O	CaO	MgO	MnO
Kaolin	45.30	39.13	0.41	0.07	0.21	0.04	0.15	0.05	0.02
Quartz	95.33	1.35	0.12	0.41	0.45	0.04	0.94	0.13	/
Feldspar	77.01	12.03	0.145	1.13	5.68	2.06	0.28	0.29	0.042
Bentonite	65.2	17.25	0.2	2.10	0.2	2.15	3.10	1.20	/

TABLE 2. Chemical composition of raw materials (wt. %)

Various formulations were dry-milled in a ball mill for 4h and subsequently wet-milled in a ball mill for 40 min. In general the size of quartz and feldspar reach a value of (45 and 53µm) respectively to increase the strength and vitrification of porcelain material [2]. The resulting slurries were passed through a 63µm sieve to calculate the residue on sieve. Values were between 5 and 7% depending on production requirements [4], [6].

3. RESULTS

XRD analyses were carried out to determine the mineralogical compositions. The results show in the kaolin the presence of kaolinite ($Al_2\,Si_2O_5\,(OH)_4$) as the main phase and halloysite ($Si_2\,Al_2O_5\,(OH)_4\,nH_2O$) as a secondary phase. Feldspar is composed of feldspar potassic ($KAlSi_3O_3$) and anorthite ($Si_2O_8CaAl_2$). Quartz is composed of quartz (SiO_2) and traces of Ca, Mg and Al. The bentonite spectra indicate the presence of quartz, feldspar, cristobalite and carbonate (calcite) and it has a high proportion of montmorillonite.

These results deduced from the elementary chemical measures analysis by ICP showed that the kaolin contains small amounts of impurities such as Fe_2O_3, K_2O, CaO and MnO; this is consistent with the white clay kaolin. The proportion of SiO_2 in the feldspar more than 50wt. % can contribute the formation of the liquid phase. The percentage of SiO_2 in the quartz from Boussaâda exceeds 80wt. % according to work's and the results obtained of raw materials used are alumino-silicate materials [7], [8]. Besides, it is important to note the iron oxide content of the samples for their use into porcelain tableware: the bentonites having a $Fe_2O_3 > 5\%$ will not be used to avoid the black core and changes on colorimetric properties of the ceramic porcelain after firing. The bentonite contains $Fe_2O_3<5\%$ and more MgO and slightly less Al_2O_3 compared to other raw materials. Measuring rheological parameters mixtures is mentioned in Table 3 after it deduces that blends with 5, 10 and 15 wt. % bentonite are rich in plastic materials such as kaolin and bentonite which caused an increase of the viscosity, the density, the residue on sieve, the pH and the thixotropy and which are shown in Figures1-4. Some mixtures such as 5 to 10 wt. % bentonite are in the ranges designated for the preparation of commercial porcelain slurries and which are: [200-350Cpo] for the viscosity, [1.70 to 1.75 g / cm^3] for the density with a residue between 5% and 7 which ensure basic pH (9.73) of the medium and which can be deduced that these values can be adapted to the preparation of mixtures intended for the preparation of porcelain materials.

Mixtures (wt. %)	Density (g/cm^3)	Viscosity (Cp)	Residue of save (%)	pH	Thixotropy		
0	1.73	342.7	5.10	8.88	350.8	354.2	358.1
5	1.74	346.6	5.66	9.07	394.4	398.8	412.3
10	1.75	349.1	5.67	9.73	396.3	409.9	419.5
15	1.77	409.8	5.72	9.92	414.3	422.8	429.8

TABLE 3. Physical properties of the porcelain slurries P_0, P_1, P_2 and P_3

The bentonite can be used in tableware formulation without any problems associated with the physical properties such as swelling and flocculation since it confers conventionally as a dispersion factor. Its introduction in weight percent with other raw materials reduced the total cost. The use of bentonite of Maghnia is limited to a maximum weight of 10 wt. %.

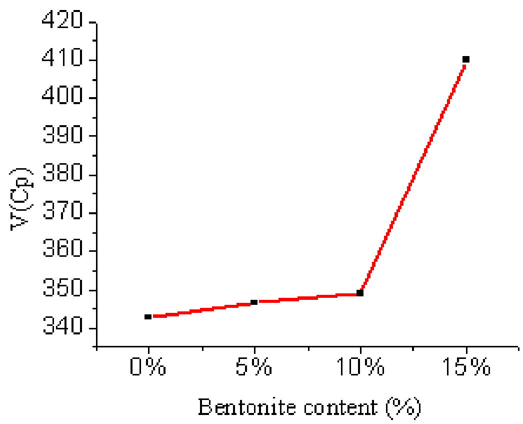

FIGURE 1 .Variation of viscosity of the mixtures 0, 5, 10 and 15wt. % of bentonite

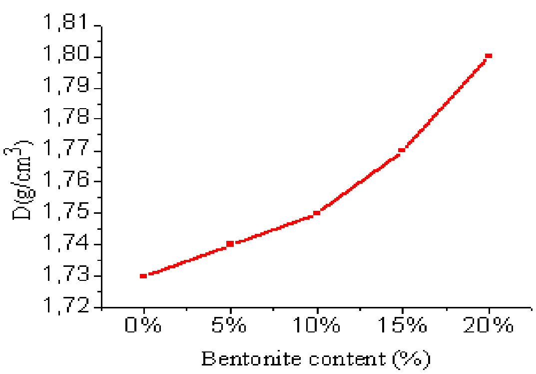

FIGURE 2 .Variation of density of the mixtures 0, 5, 10 and 15 wt. % of bentonite

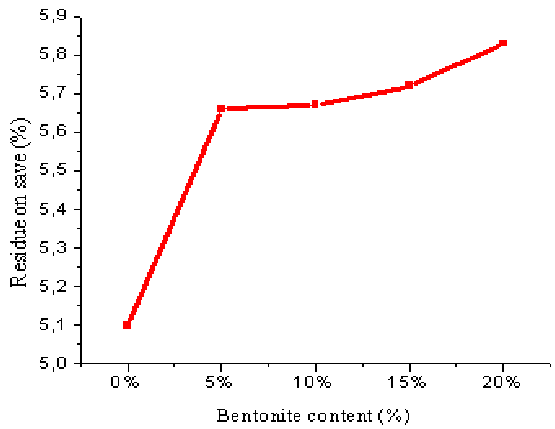

FIGURE 3 .Variation of residue on sieve of the mixtures 0, 5, 10 and 15 wt. % of bentonite

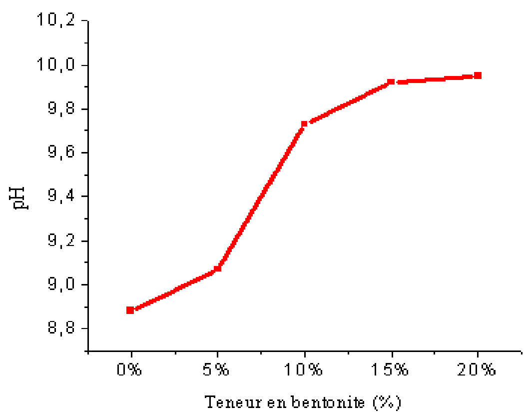

FIGURE 4 .pH variation of the mixtures 0, 5, 10 and 15 wt. % of bentonite

4. CONCLUSIONS

This work was focused on the use of bentonite at different contents in a mass composition intended for the production of ceramic products type porcelain tableware. The interest referred to in this work was involved improving the rheological properties of these products in an economic benefit. The addition of bentonite led to a good slip which will therefore be a compromise between a high viscosity, rigidity, permeability and the weakest water absorption as possible of the layer paste deposited on the mold to obtain a thickness sufficient in a limited time, these variations are strongly related to electrolytes that provide a basic pH of the medium. The addition of the bentonite clay has a positive influence on the rheological properties of the porcelain up to a maximum weight of 10 wt. %.

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