The Use of Raw and Calcined Diatomite in Art-Tile Bodies

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ABSTRACT: In this study, the changes in the physical and mechanical properties of the art-tile bodies with high silica content were investigated after raw and calcined diatomite addition For this purposes, raw and calcined diatomite were added at 18% to the traditional art-tile bodies having high silica content, the bodies were than pressed and fired at 900°C which is an accepted firing temperature for traditional art-tile bodies The changes m the bodies were determined by some physical and mechanical tests while the mineralogical variations were examined by the XRD patterns As a result, the fired strength of the bodies with 18% raw and calcined diatomite addition was increased by 2 5 and 3 times, respectively Another interesting result obtained with such an addition was that the density of the bodies was decreased by 9 42% compared to the reference body

1 INTRODUCTION

Art-tile and ceramic industry have played a very important role in the formation of Turkish culture and m enhancing the traditional arts Izmk and Kütahya have become the major centers for the production of ceramic ware during the Ottoman term At the end of the 18^{th} Century, the production at Izmk had stopped and Kütahya became the only centre of this art and has survived until the present day In 16^{th} century, the ceramic industry has reached a flourished point both in technique and in art In this period, there has been an important development m under-glazmg technique which enabled the preservation of the figures, colours for a long time and provided a better appearance for the figures (Gyozo 1986) 16^{th} century Izmk and Kütahya art-tile bodies contam silica, glass frit and bentonite with 80% montmonllonite In this period, quartz, quartz sand and fhntstone were used as the silica souice (Atasoy, 1989)

As well known, diatomite is also an important silica source in the nature which is a fossil type of sedimentary rock, occurred by the accumulation of siliceous shells of diatomes (Onem 2000, Bozkurt 2000, Karaman&Kıbıcı 1999) The most important property of the diatomite is its low density Although the wet density varies between 1 9-2 4 gr/cm^3, it can decrease down to 0 4 gr/cm^3 after drying Another important property of the diatomite is that it has an average particle size of 50-100 *jim* (Breese 1994, Harben 1995) Therefore, diatomite is used mainly as a filtration, filler and insulation material (Bentli 2002, Kokturk 1997, Karadeniz 1996, Mete 1988) The research on diatomite and its industrial use has recently been increased m Turkey Bentli et al (2004) has studied the physical and chemical properties of Kütahya Alayunt diatomite together with its processing possibilities Aruntaş et al (1998) investigated the properties and the industrial use of Çankırı and Ankara dıatomıtes while Mete (1985) searched the benefıcıatıon of Kutahya-Alayunt dıatomıtes and their use m insulating brick production Ozbey and Atamer (1987), on the other hand, have made some proposals on the production and utilization of commercial dıatomıtes

High silica wall tiles currently produced in Kütahya are thicker and larger than traditional Kütahya tiles One tile with 25x25 cm size weights about 1550 1560 gr and this causes some problems both in transportation and in mounting to the building since it increases the total weight of the structure In this research, the modification in the physical and mechanical properties of the art tile bodies produced by the addition of raw and calcined diatomite was investigated

2 EXPERIMENTAL STUDIES

2.1 Material

The quartz sand, Clay-1, Clay-2 and diatomite samples used m this research were collected from Istanbul, Eskişehir and Kütahya, respectively In order to obtain calcined diatomite, raw diatomite was first dried at 110°C for 12 hours The dried diatomite was then fired in an electrical chamber furnace at 1000°C for 1 hour Furnace temperature was increased as 1°C per minute to the final level Calcination temperature was determined by examining the TG-DTA curve of the raw diatomite (Bentli vd 2004) Chemical analysis of the raw and calcined diatomite was made using the ICP equipment (Perkm Elmer Optima 3000) However, an XRF instrument was used for the analysis of quartz sand, Clay-1 and Clay-2, the result was given Table 1 Characterization of raw and calcined diatomite was made by Rigaku Mimflex diffractometer with CuKa radiation and XRD diffractograms are given m Figure 1 As seen from Figure 1, diatomite ıs m amorphous state and there are cnstobahte picks due to the calcination temperature of the calcined diatomite The densities of the raw, calcined and silica sand and their residues of sieve 63 fim are given in Table 2

Table 1 Chemical composition of the raw materials

Parameter (%)	Raw Diatom.	Calcined Diatom	Quartz Sand	Clay-1	Clay-2
SiO_2	89 86	93 60	87 02	5012	68 12
Al_2O_j	162	124	7 12	6 76	14 98
Fe_2O_3	040	0 61	0 65	2 64	1 12
TIO2	0 05	005	0 32	0 42	0 10
Na_2O	0 77	0 55	102	5 22	100
K_2O	0 18	0 20	0 77	146	162
CaO	128	1 17	0 49	3 53	2 58
MgO	0 18	0 22	012	14 60	167
Firing Loss	5 66	0 51	249	1141	646

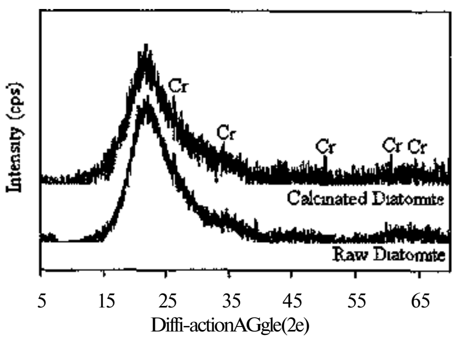

Figure 1 XRD Diffractograms of the raw and calcined diatomites (Cr Cnstobahte)

Table 2 The densities of the raw, calcined diatomites and silica sand, their residues of sieve 63 *jira.*

Property	RawDia	Calcined Dia	Quartz
Wet Density (gr/cm^3)	TÔ1	201	~
Dry Density (gr/cm^3)	0 374	0 384	2 65
63 um residue (%)	6	6	72 9

2.2 Method

In this research, new wall tile recipes were prepared by replacing the quartz sand in the original recipe (R) with raw and calcined diatomite at 18% (Tatar et al 2004) The prepared recipes are given in Table 3 In these recipes, the SIO2 content was arranged so as to be 72%

Table 3 Wall üle recipes (%)

Raw Material	R	D	KD
Quartz Sand	62	42	42
Raw Diatomite	-	18	
Calcined Diatomite	-	-	18
Clay-1 +Clay-2+Fluxes	38	40	40

The raw materials prepared according to the recipes given above were comminuted in a ball mill for 30 minutes The comminuted materials were then dried at 105°C for 24 hours and undergone size reduction The crushed material was sieved through 1500 *pm* screens to obtain granules These granules were then dry pressed at 160 kg/cm^2 pressure and finally fired in an electrical chamber furnace at 900°C for 1 hour Furnace temperature was arranged to increase as 3°C per minute

2.2 Physical tests

Total shrinkage, porosity, water absorption and density tests were carried out in order to determine the physical properties of fired art tile bodies

2 2 7 *Strength tests*

The variation in the fired strength of the bodies with raw and calcined diatomite addition compared to the reference body is seen in Figure 2 As seen from the figure, the fired strength of the reference body was increased to 159 kg/cm and 196 4 kg/cm^2, respectively after 18% raw and calcined diatomite addition This result can be explained by the finer particle size of the diatomite than quartz sand which causes more compact structure during sintering by filling the pores Sintering of the materials with high silica content is accomplished by liquid-phase sintering method Liquid phase wets the solid particles and capillary pressures of up to 0 007 kg/cm^2 are created in fine channels between the particles Capillary pressures in fine materials are higher and sintering occurs easily (Geçkınlı 1991)

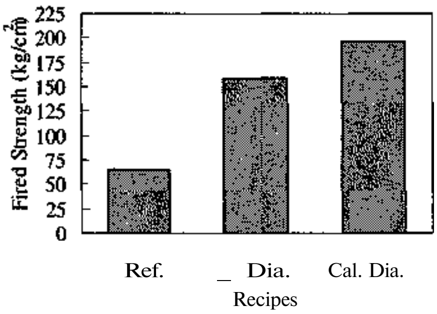

Figure 2. The variation in the fired strength of the bodies.

When XRD diffractograms are examined (Figure 3), anorthoclase development was found to be higher in the bodies with raw and calcined diatomite addition than the reference body. This is seen to be the main reason for the increase in the fired strength (Strnad, 1986). Therefore, diatomites when used, affect the property and the performance of the final product positively (Bozkurt, 2000).

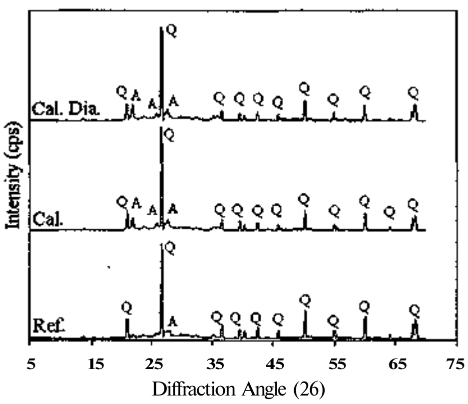

Figure 3. XRD diffractograms of the bodies (Q: Quar.;, A: Anorthoclase).

2.2.2 Shrinkage tests

Total shrinkage variations in the art tile bodies are seen in Figure 4. When the figure is examined, it is seen that the raw and calcined diatomite addition increases the total shrinkage of the bodies.

The increase in the total shrinkage and in the fired strength values of the bodies reflects better sintering conditions. The other explanation for the increased shrinkage is that diatomite has a firing loss of 5.59%, while the quartz sand has a firing loss of 2.15%.

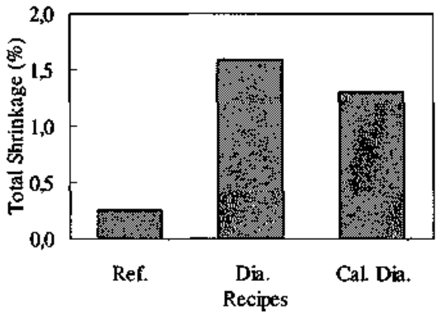

Figure 4. Total shrinkage variations for the bodies.

2.2.3 Water Absorption-Porosity Tests

Apparent porosity measurements of the art tile samples were made by using the Archimed weighting instrument. Water absorption-porosity values of the samples are given in Figure 5. Water absorption-porosity values of the bodies were increased compared to the reference body after diatomite addition since diatomite has more porous structure. However, this increase is in the acceptable range according to the Standard, TS EN 159.

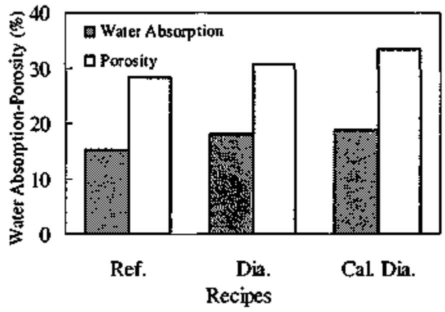

Figure 5. Variation in the water absorption-porosity values of the bodies.

2.2.4 Density Tests

The variation in the density of the high silica art tile bodies is given in Figure 6. As seen from Figure 6, the density of the bodies with raw and calcined diatomite addition were found to be 1.75 gr/cm^3 and 1.73 gr/cm^3, respectively, while the density of the reference body was 1.91 gr/cm^3. This result was explained by the lower density of both raw and calcined diatomite used than quartz sand. Moreover, the bodies with both diatomite additions were more porous than the reference body. This result brings about some advantages in transportation and m mounting the art tiles

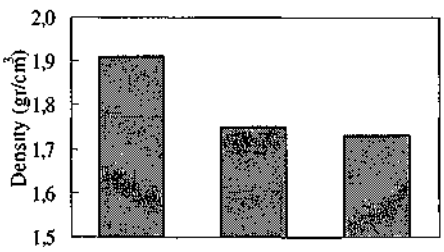

Figure 6 Density variations in the bodies

3 RESULTS

The results that can be derived from the tests earned out on the high silica art tile bodies after replacing the quartz sand with raw and calcined dıatomıtes by 18% are summarized below

- Fired strength values of the bodies were increased by 2 5 and 3 times after raw and calcined diatomite addition, respectively
- Raw and calcined diatomite addition increases the total shrinkage of the art tile bodies
- Raw and calcined diatomite addition increases water absorption and porosity values This is caused by the porous structure of the diatomite
- The density of the bodies with raw and calcined diatomite addition was decreased by 8 37% and 9 42%, respectively when compared to the reference body
- Finally, it was proven that raw and calcined diatomite can be added to art tile bodies both to increase the fired strength and decrease the density of the bodies

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