3D Filtration Membrane prepared from ceramic

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Abstract

A ceramic membrane (CFM) was prepared from Iraqi raw materials by using two main types of clay, white clay soil (Kaolin) and the red clay soil. The red clay soil was used for its low melting point, which is lower than kaolin and matured in low firing temperature, in addition to its higher porosity compared to kaolin. The manufacture of this (CFM) was Slip Casting Method, and different additives were used in ratios as pores forming agents in (CFM) such as sawdust and porcelanite rock. These additives were added in ratios (5%, 10%, 15%). Porcelanite rock was used in three grades of particle size (106, 75, 53) μm. The result revealed that the porosity and absorption of the filter increased linearly with an increase in the amount of the additives materials. On the other hand, its density inversely related to the porosity. The porosity and absorption increased on increasing porcelanite particle size, while density reduced on increasing porcelanite particle size. The result showed that porosity and absorption of the filter increased linearly with an increase in the additives materials amount, while porosity was inversely affected by the density of ceramic filter. Also, porosity, absorption increased with increasing porcelanite particle size, while density reduced with increasing porcelanite particle size.

Keywords
Ceramic membrane (CFM); Kaolin; red clay; porcelanite rock; porosity; absorption

1. Introduction

Ceramic Filtration Membrane in recent decades has extensively been used in the sector of wastewater and water treatment by means of grades of benefits over standard treatment of water technology. Ceramic membrane was manufactured with good chemical stability, resistance to high temperature in wastewater and water treatment and high mechanical strength. It is a material which is neither a metal, a semiconductor nor a chemical compound [1]. It follows that the borides, oxides, nitrides, resistance to high temperature in wastewater and water treatment, carbides, silicides, and silicates of all metals are ceramic [1]. The separation membrane is prepared from inorganic ceramic material and molded and calcined high temperature such a way it posse separation characteristic. The inner layer contains a lot of pores, with a porosity greater than 30 % and the average pore size commonly 1~10μm, Wang Wu 2006 [2]. The size and form of grain and presence of porosity characterize the ceramic microstructure material. Ceramic membrane classified according to different filter modules [2], they can be divided into roll membranes, flat membranes, tubular membranes and hollow membranes; and can be divided into and cross-flow filtration and terminal filtration according to the filtration method; the size of membrane can be divided into ultrafiltration membranes, nanofiltration membrane and microfiltration membranes.

Advantages of ceramic membrane are:
• Abrasion resistance, high direct or back pressure may be used to regenerate the film, no damage or deformation under high pressure, erosion resistance, very high mechanical strength

• Organic solvents and alkali and acid resistance, high chemical stability and high oxidation resistance.

• Resistance to temperature is very high; usually it works at 400 °C and the maximum temperature it can withstand is 800 °C.

• anti-microbial and anti-bacteria properties is very strong. It is useful for biological and medical engineering.

• High separating efficiency and the distribution of pore size is narrow.

• Suitable for food and drug treatment as it is non-toxic.

And the disadvantages of ceramic membranes are: Difficulties of forming and assembly of the membrane due to brittle behavior of ceramic material and incompatibility [7]. Porosity is the most important property to describe the porous material, which indicates the volume of cavity. It represents the fraction of the whole volume of pore space to obtain the parameters such as thermal conductivity, diffusion, permeability and mass transfer. Other porie from porogient agent in ceramic filter which contribute to increase the flow rate [7]. In membrane manufacturing from ceramics, additives modify the hydraulic properties of ceramic because they leave micro pores when firing. These pores are connected together to make micro channels through which the filtration process is carried on [4]. The more additive added to the mixture the more porosity is obtained throughout the ceramic filter, but less ceramic strength is created [8]. Completely different ceramic raw material mixes by weight percent were used to investigate the effects of adding the three types of additives. Three types of organic materials were chosen as additives and examined in different percentages. The present research aims to manufacture ceramic membrane from additives of sawdust and clay and porcelanite rock and to illustrate the physical properties of the produced materials.

2. Materials and Methodology

Two main types of raw materials are available for producing local ceramics membrane. The white clay soil viz. Kaolin which is obtained from Akashat mines, West of Iraq, and red clay soil, and most pure red clay soil from Khan Beni Saad, North East of Baghdad, both of them are locally available. The red clay soil and kaolin are usually used in the ceramic artistic pottery work by firing at higher degree to mature. Samples of every type were bought from local markets. They were analyzed by using x-ray fractions at the laboratories of the Iraqi State of Geological Survey.

The sample of red clay soil was well prepared and was ready to be used for ceramic manufacturing. The red clay soil was washed and kept in the washing tank until all the material got settled to prevent any material loss with the washing water. This was done to ensure that there are no dissolved salts and it was grinded before it was used. The material dried at room temperature after washing. The remaining moisture was removed by using an oven at 110°C for 24h. The red clay soil was then well grinded by using a rubber hammer and then by a blender, then the clay soil was ready to be used.

2.1 Additives Materials Preparation

2.1.1 Sawdust. Saw dust which can be readily used by washing with distilled water and grinded to (53 μm) after air drying.

2.1.2 Porcelanite rock. The raw stone of porcelanite was obtained from the Iraqi State of Geological Survey which was crushed into large particles, ground into powder, and sieved to micron size and then washed with water and left to dry on oven for 110°C for 24 h, then sieving to three gradients of particle sizes (106, 75, 53 μm). Sawdust and the treated porcelanite rock were mixed with varying
ratios (5 %, 10 % and 15 %) are mixed with clay to get the best gradients of particle size as shown in Table 1.

| No. | Clay | Sawdust-grain size 53 | porcelainite-grain size 106 | porcelainite-grain size 75 | porcelainite-grain size 53 |
|-----|------|------------------------|----------------------------|---------------------------|---------------------------|
| a   | % 95 | -                      | % 5                        | -                         | -                         |
| b   | % 90 | -                      | % 10                       | -                         | -                         |
| c   | % 85 | -                      | % 15                       | -                         | -                         |
| d   | % 95 | -                      | -                          | % 5                       | -                         |
| e   | % 90 | -                      | -                          | % 10                      | -                         |
| f   | % 85 | -                      | -                          | % 15                      | -                         |
| g   | % 95 | -                      | -                          | -                         | % 5                       |
| h   | % 90 | -                      | -                          | -                         | % 10                      |
| i   | % 85 | -                      | -                          | -                         | % 15                      |
| j   | % 95 | % 5                    | -                          | -                         | -                         |
| k   | % 90 | % 10                   | -                          | -                         | -                         |
| l   | % 85 | % 15                   | -                          | -                         | -                         |

Table 1. Ratio of mixes

2.3 Preparation of 3D ceramic modules
A 3D Ceramic module are prepared by slip casting by using gypsum mold, with the following dimensions; height: 13 cm, thickness 0.6 cm, diameter 6 cm (Fig.1). The modules were left to dry for 7 days, and then fired in an electric furnace at 1000°C.

![Figure 1. Mold and module of ceramic](image)

3. Results and Discussion
Table 3 shows the chemical composition of clay soil, alumina, Al₂O₃ and silica, SiO₂, more in Kaolin than that of red clay soil and they are considered the main components of ceramic structure. Iron
trioxide, Fe$_2$O$_3$, and other oxides in the red clay soil are higher than that in Kaolin, and they act as fluxes in ceramic mixtures and play a vital role in lowering the melting point during the firing process. The ceramic manufacture from red clay soil is matured in lower firing degree than Kaolin. The loss on ignition, LOI, substances which volatizes and outgases during the firing process, in Kaolin was lower than that in red clay soil. That is because most of the losses due to the chemically bonded water, while, in the red clay soil it’s due to other impurities like organic materials, also the chemically bonded water. The specific gravity of material used also occurred at the laboratories of the Iraqi State of Geological Survey (see Table 2 and 3).

Table 2. Chemical composition of clay soil

| Clay soil | SiO$_2$ | Al$_2$O$_3$ | Fe$_2$O$_3$ | CaO | MgO | Na$_2$O | K$_2$O | SO$_3$ | TiO$_2$ | LOI | Total |
|-----------|---------|-------------|-------------|-----|-----|---------|-------|-------|--------|-----|-------|
| Red clay  | 39.96   | 10.30       | 5.32        | 18.32 | 4.19 | 0.91    | 1.55  | 0.07  | -      | 18.26 | 98.88 |
| Kaolin    | 47.62   | 35.86       | 0.79        | 0.17 | 0.33 | 0.25    | 0.40  | <0.07 | 1.07   | 12.88 | 99.44 |

Table 3. Specific gravity of compound

| compound   | G.S  |
|------------|------|
| Red clay   | 2.67 |
| porcelanite | 2.15 |
| sawdust    | 2.10 |

The physical test results are illustrated in figures 2 to 7. The tests of apparent porosity and bulk density are according to ASTM-C373, 2006 [6]. After measuring the saturated and dry weight of the specimens the following were found:

Bulk density = $\frac{w_1}{(w_2-w_3)} \times \rho_w$

Apparent porosity = $\frac{(w_2-w_1)}{(w_2-w_3)} \times 100\%$

% water Absorption = $\frac{(w_c-w_d)}{(w_d)} \times 100\%$

From figures 2 to 7, the effect of additives (sawdust and porcelanite rock) was found versus the apparent porosity and absorption of the ceramic filter and density. The porosity and absorption of the filter was linearly with an increase in the amount of the additive’s materials [8]. The porosity and absorption of red clay before any addition was 18% and 15%, respectively, and when addition the progrant agent (sawdust, porcelanite rock) the porosity was 42.22% at ratio 15% of sawdust and 31.19% at ratio 10% of porcelanite rock of particle size 75 μm while the ceramic filter density was inversely proportional to the porosity. So, when the ratio of additive further was increased, the density of specimens were rapidly increased.

Porosity increased with increasing porcelanite particle size, it is due to this fact, a big number of pores were left due to a large particle. For most ceramic materials, while the density suggests the reverse conduct reduce with increasing porcelanite particle size [5], and porosity decreased as the fraction of the fine particles added was increased to a certain value, after which the porosity started to increase as the fraction of fine particles was further increased [9].
Figure 2. Relation between additive ratio and absorption

Figure 3. Relation between additive ratio and porosity
Figure 4. Relation between additive ratio and absorption, porosity and density for 106 porcelanite grade
Figure 5. Relation between additive ratio and absorption, porosity and density for 75 porcelainite grade.
Figure 6: Relation between additive ratio and absorption, porosity and density for 53 porcelanite grade
4. Conclusions

The pores of sawdust is greater than porcelainite rock, which leads to high porosity and low density. The 10 percent ratio of sawdust is the best selected ratio that made porosity of 36.89%. The ratio of 15% sawdust gives brittle filter and difficult to form by slip casting method.

The particle size of (75)μm for the porcelantine rock gives the best ratio of porosity and absorption.

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Figure 7: Relation between additive ratio and density of sawdust