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Production of Water Filter from Porcelanite by Dry pressing

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Abstract

Filtration is the process of removing suspended objects from the fluid by passing it through a porous filter. In this study porous ceramic water filter was preparation from Iraqi local porcelanite and Iraqi white kaolin with ratio (10%) as a binding material, and natural additives (wheat flakes) with ratio (5,10,15,20,25, and 30) %. Ceramic materials used in the manufacture of the filter are environment - friendly materials and harmless. Filter is not expensive and easy to prepare, the specimens were formed by dry pressing then fired at (1200) ˚C, to evaluation of prepared filters the following tests were performed, linear shrinkage, loos in mass, apparent porosity, water absorption, apparent density, permeability as physical properties, compressive strength and diametrical strength as mechanical properties. The result shows that the linear shrinkage decreased to 0.6 %, loos in mass increased to 24.25 %, apparent porosity increased to 55%, water absorption increased to 50.99%, apparent density decreased to 1.07(g/cm^3), permeability increased to 0.131(cm2/ bar. min), compressive strength decreased to 1 (MPa) and diametrical strength decreased to 3 (MPa) with adding ratio (30%) of wheat flakes (W.F), scanning electron microscopy (SEM) using to studying the microstructures which showed homogenies distribution of pores form a net in filter, adding wheat flakes with (30) % give highest pores.

Keywords: Water Filter, porcelanite, wheat flakes, porosity, permeability.

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تحضير فلتر ماء من البورسلينايت بالكبس الجاف

ايناس محي هادي و صفا لؤي جاسم

قسم العلوم التطبيقية – الجامعة التكنولوجية – بغداد – العراق

الخلاصة

الفلترة هي عملية ازالة المواد الضارة من المائع المار عبر الفلتر المسامي. في هذه الدراسة حضر فلتر ماء سيراميكي مسامي من البورسلينايت المحلي والكاؤلين العراقي الابيض وبنسبة (10%) كمادة رابطة، ومواد طبيعية (قشور الحنطة) وبالنسب التالية (30,25,20,15,10,5) %. المواد السيراميكية المستخدمة في تصنيع الفلتر هي مواد صديقة للبيئة وغير مؤذية. الفلتر غير مكلف وسهل التحضير، النماذج شكلت بالكبس الجاف وحرقت بدرجة حرارة (1200) م° لتقييم الفلتر المحضر اجريت الاختبارات التالية، التقلص الطولي، الفقدان بالكتلة، المسامية الظاهرية، امتصاص الماء، الكثافة الظاهرية، النفاذية كخصائص فيزيائية و مقاومة الانضغاط والمقاومة المحورية كخصائص ميكانيكية. اظهرت النتائج نقصان التقلص الطولي الى 0.6 %، زيادة الفقدان بالكتلة الى 24.25 %، زيادة المسامية الظاهرية الى 55 %، ازداد امتصاص الماء الى50.99 ونقصت الكثافة الظاهرية الى 1.07 (غم/سم ^{3})، ازدادت النفاذية الى 0.131 (سم2/ بار. دقيقة)، ونقصت مقاومة الانضغاط الى 1 (ميكا باسكال) ونقصت المقاومة المحورية الى 3 (ميكا باسكال) عند اضافة نسبة (30%) من (قشور الحنطة)، استخدم المجهر الالكتروني الماسح لدراسة البنية المايكروية واظهرت توزيع المسامات بشكل متجانس مكونه شبكة ضمن الفلتر، اضافة قشور الحنطة بنسبة (30)% تعطي المسامية الاعلى.

الكلمات المفتاحية: فلتر ماء، بورسلينايت، قشور الحنطة، المسامية، النفاذية.

Introduction

Filter is an instrument or device that eliminates something from whatever passes through it. So, the ceramic materials used in the manufacture of the filter are materials of nature, environmentally friendly and harmless compared with other materials [1]. Water purification is main factor because water pollution affects millions international and it is expected to worsen over the coming years and decades. It is projected that in 2010, (1.8) billion people consuming water thought (dangerous) and (783) million regularly used water sources unprotected from contamination [1]. Significantly Kids are affected by ingestion of contaminated water: 15% of deaths in kids under five years old are related to approximately (2.5) billion yearly. That means every year (3.4) million kids die as a direct result of diarrhea and other diseases caused by water-borne microbes, making it the second leading cause of death of children, mostly in (low - middle) countries [2]. Ceramic water filteration can be defined as a method that uses a porous ceramic medium to filtrate water from contaminants or microbes. Water filters have evolved out of necessity, first to improve bad tastes and further to remove contaminants that can cause diseases, then to eliminate materials that affect appearance [3]. Filtration: is an old known and very effective process for eliminating pathogens from water. Ceramic filters are especially desirable because of their ease of fabrication and use low cost, and their ability to filtrate the water from bacteria [4].

The presence of clay filters can be significantly improved by the use of burnout materials which increase flow rate by creating a network of pores. Low- cost clay filters for drinking water purification in developing countries is diversified, [5]. The advantages of locally produced ceramic filters that they are portable, light in weight, affordable and require low-maintenance [6]. The requirements for water filtration different for regions depending on impurity properties such as chemicals, metals organic matter and microbes. Some of the point-of-use processes and instruments for eliminating the above-mentioned impurities are solar disinfection, chlorination, bio-sand filters and ceramic filters [7].

Filter works as a physical wall made from clays and it is an effective technique for drinking water treatment and efficiency depends on the materials type filtration conditions of heat and pressure the competence of the filter depends on the pores. It should be reasonable to make the filter as efficient in water permeability [8 -10]. Porcelanite is one of the important industrial muddy rocks. The adsorption ability of porcelanite is due to the large surface area within the structures of its components (cristobalite) and (tridymite) [11].

Adsorption ability for porcelanite made it main for getting rid of the environment from the different pollution. It has a varied uses, such as fillers, accessory agent, storage medium, carrier, and catalyst carrier. Its industrial importance rises from its physical properties represented by the porosity, fineness of pores, adsorption power, lightweight and low heat conductivity [12].

Many academics have been studied (Iraqi porcelanite) as a filter media to remove undesired materials via a traditional powder technique. Zyad in 2013[13], prepared ceramic water candle filter made from Iraqi raw materials; kaolin clay, coal and porcelanite in different ratios. Shukur et.al. in 2014 [14], have studied the suitability of (Iraqi porcelanite) as industrial filters for sulfur refining and food products. Erhuanga et. al. in 2014 [15]. as studied the (Iraqi porcelanite) to eliminate heavy metals from industrial wastewater. The Aim of this study is an attempt to Manufacture of Water Filter from local porcelanite and Kaolin as raw materials with Natural additives like Wheat flakes.

Materials and methods

Materials

Porcelanite was obtained in cooperation with establishment of geological survey, in Baghdad, Iraq. (Western desert mines). It contains a high percentage of (SiO_2) as shown in table 1. Porcelanite is Iraqi crude rock is available in local quantities for economic purposes.

The practical procedure for preparing rocks is crushing then, milling, the powder was sieved by using a sieve shaker as shown in table 2. Kaoline was added with particle size ≤ 63µm to Iraqi porcelanite as a binding material, it contains high ratio of SiO_2 as shown in table 1, with natural addition (W.F) with ratios (5,10,15,20,25, and 30) % was obtained locally and then milled, sieved and added to the mixture with different weight table 3.

Table 1: Chemical analysis of material by (XRF)

Oxide %	SiO_2	Al_2O_3	CaO	Fe_2O_3	TiO_2	K_2O	Na_2O	MgO	SO_3	Cl	P_2O_5
Porcelanite%	75.39	1.35	3.47	0.87	0.13	0.12	0.90	1.77	0.080	0.73	1.38
Kaolin%	49.38	32.72	1.19	2.07	1.08	0.44	0.22	0.18	0.05	—	—

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Table 2: Particle size of Materials

Stage	Temp.°C	Heating time (hr)	Socking time (hr)
First	25-700	3	2
Second	700-1000	2	1
Third	1000-1200	1	2

Table 3: Compositions and Filter Samples

Particle size	Porcelanite %	Kaolin %	W.f %
μm	....125≥	…≤63	106≤W.F≤0.75

Table 4: Stages of firing

Mixture (Porcelanite and Kaolin) %	W.F %
100	0
95	5
90	10
85	15
80	20
75	25
70	30

Methods

The specimens were prepared by using (dry pressing method) figure 1, then they were fired at (1200) ˚C stages of firing shows in table 4.

Testing

Physical Test

Linear Shrinkage (L.SH)

The linear shrinkage of all specimens was determined by measuring the differences in diameters before and after sintering.

(L.SH.) as shown in equations (1) according to (ASTM 326).

$$\mathbf{L.SH.} = \frac{Lo-L}{Lo} \times 100\% \qquad (1)$$

L_0: original length of Specimen (before firing).

L: ending length of Specimen.

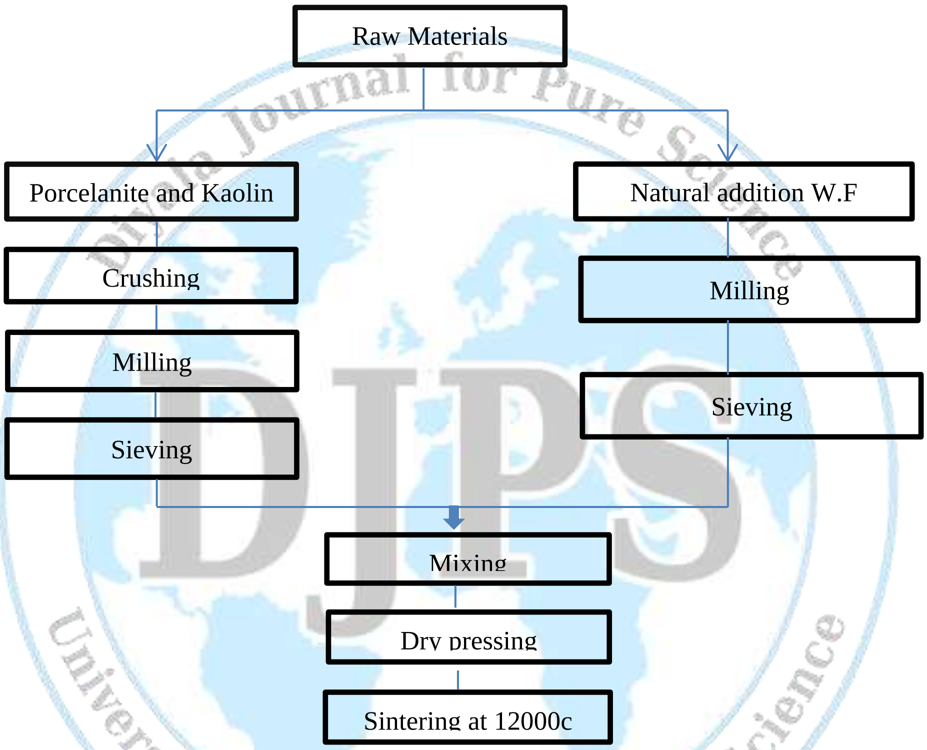

Figure 1: Preparation of the Samples

The loss in Mass (L.M)

It is usually determined by using vernier to measure the initial and final mass of specimens before and after the firing process.

(L.M.) is calculated by the following equation (2) according to (ASTM C1407).

$$\text{L.M.} = \frac{Mo - M}{Mo} \times 100\% \qquad (2)$$

M_0: original mass of specimen (before firing).

M: ending mass of specimen.

Apparent Porosity (A.P)

(A.P) of the specimens was measured by the archimedes method, using ASTM(C373). (A.P) was calculated by the following equations 3:

A.P. % = $\boldsymbol{Ws - Wd\ / Ws - W\,i\ \times 100\%}$ **(3)**

W_d: mass of the dry specimen (g).

W_s: mass of specimen being immersed in water (g).

W_i: mass of specimen being infiltrated with water(g).

Water absorption (W.A)

(W.A) of the specimens was measured by the archimedes method, using ASTM(C373). (W.A) was calculated by the following equations 4:

W.A. = $\boldsymbol{Ws - Wd\ / Wd\ \times 100\%}$ **(4)**

Apparent Density (A.D)

(A.D) of the specimens was measured by the archimedes method, using ASTM (C373). (A.D) was calculated by the following equations 5:

A.D. = $\boldsymbol{Wd / Ws\ - Wi\ \times 100\%}$ **(5)**

Permeability

In this method, the constant pressure of water is applied over the porous filter ceramic specimen. The permeability of filter calculated according to darcy law as follows.

K= $\boldsymbol{VT / Apt}$ **(6)**

K: permeability

V: collected volume of water (cm^3).

T: thickness of the specimen (cm).

A: cross-sectional area of the specimen (cm^2).

P: pressure (bar).

T: time required to collect the volume of water (min).

mechanical Test

Compressive strength (C.S.)

(C.S.) was measured by using three-point test according to ASTM (C1116). The compressive strength calculated according to equation 7:

$$\text{C.S.} = \boldsymbol{F/A} \qquad (7)$$

F: force (N)

A: area (mm^2).

Diametrical strength (D.S.)

The mechanical resistance test was performed using diametrical strength is measured by using hydraulic pistons. Put the specimen vertically under the piston.

(D.S) was calculated by the following equations (8) according to (ASTM C773).

$$\text{D.S} = \frac{2F}{\pi d D} \qquad \ldots\ldots\ldots (8)$$

D: diameter of the sample (mm).

d: thickness of sample (mm).

Result and Discussion

The result of Physical test

Apparent Porosity and Water absorption

The porosity and water absorption are closely related because they are affected by the same factors, (apparent porosity) be contingent to materials used, the ratio of addition, particle size, the shape of addition and temperature of the firing. The pores ratio depends on the formation pores and airways in the form of the ceramic body in the initial stages of sintering and then fill the pores with the liquid phase formed in the final stages of sintering, Figure 2 shows the apparent porosity changed with changing in the ratio of addition (W.F). The apparent porosity increased with increasing of addition ratio and continues to increase with increased ratio of (W.F) added to 30%, because the particles of the additives will burn during the sintering process, The ceramic body works to create pores as a result of the emergence of carbon dioxide gas, which is increased with increasing of addition ratio, this result is identical to previous studies, they concluded that there is an increasing in porosity depending on the number of additives [16] and [17]. Whereas, the increase of (W.F) for it decreases the percentage of the Kaolin, which produces the liquid phase during the sintering process, so that the liquid phase is unable to fill the pores that generated, so the ratio of apparent porosity increased with increasing (W.F). The apparent porosity is associated with the water absorption, which represents the amount of water absorbed by the pores. As the pores increase, the absorption ratio increases. In other words, the absorption rate follows the same apparent porosity behavior as shown in figure3 shows the Water absorption changed with changing in the ratio of addition (W.F).

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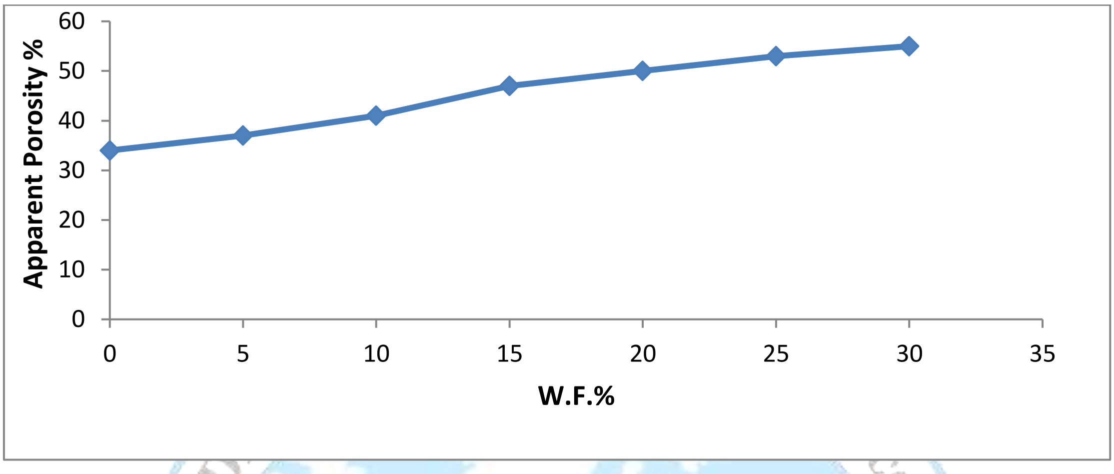

Figure 2: Relationship between A.P and W.F%

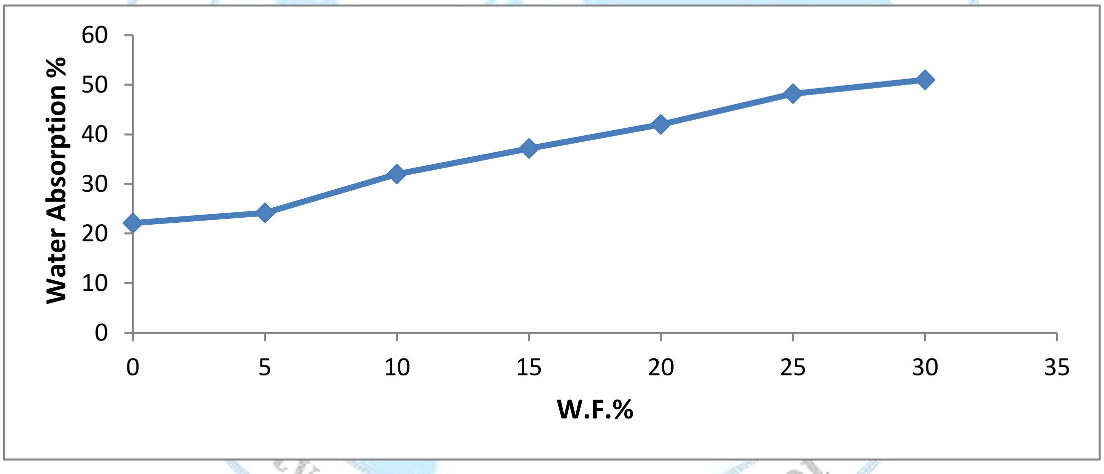

Figure 3: Relationship between W.A and W.F%

Apparent Density

The result of apparent density is reverse to the apparent porosity, the increasing in apparent porosity leads to a decrease in apparent density. The apparent density depends more on raw material which that used, sintering temperature and soaking time. Figure 4 shows the apparent density changed with the changing the ratio of addition (W.F). The apparent density decreased with increasing addition of (W.F).

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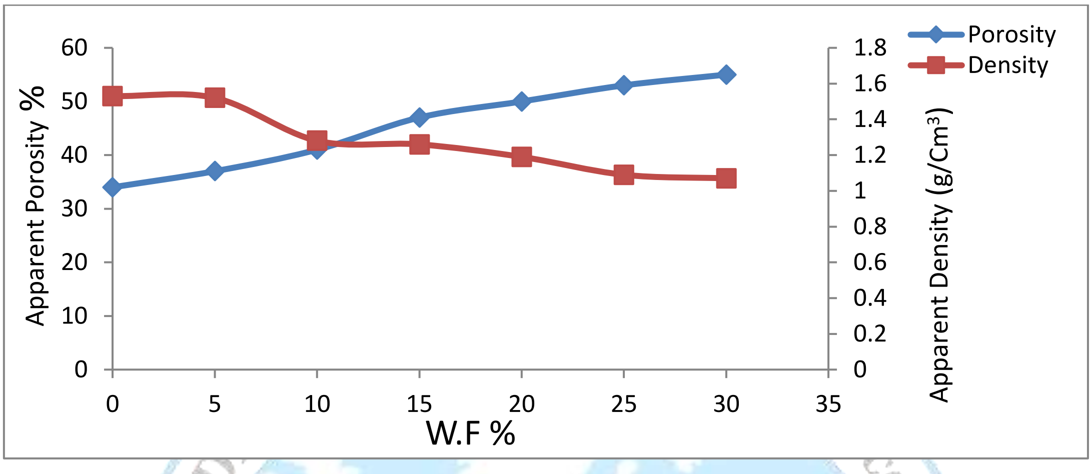

Figure 4: Relationship between A.D (g/cm^3) and A.P%

Loos in mass

The loss in mass increased with increasing of (W.F) addition as shown in figure 5. The sintering process resulting from burning of (W.F) and creating in a loss in mass Kaolin lightweight air gaps. Figure 5 shows the loos in mass changed with changing in the ratio of addition (W.F). The loos in mass increased with increasing addition of (W.F).

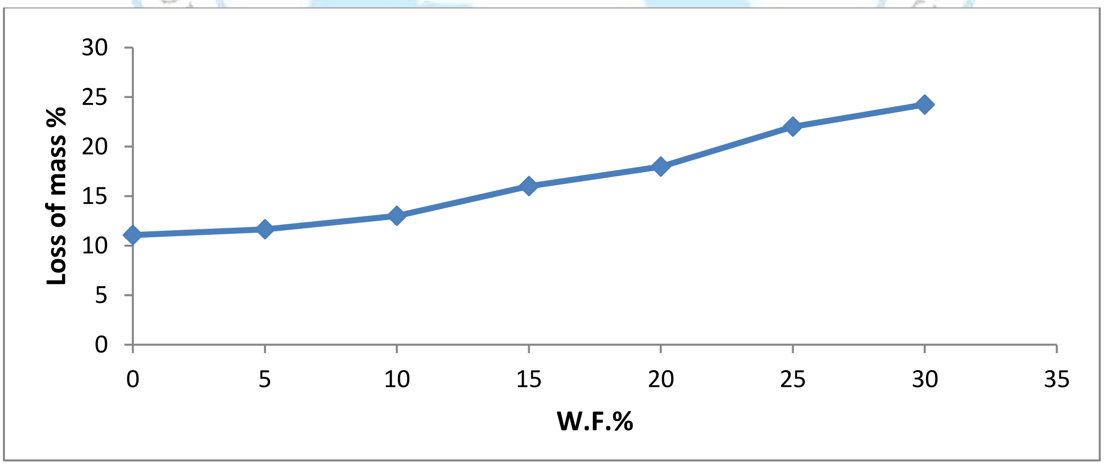

Figure 5: Relationship between L.M and W.F%

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Linear shrinkage

Decrease in kaolin quantity is Manager reductions of the total linear shrinkage because of the amount of liquid phase which causes shrinkage was decreased so, linear shrinkage decreased with the decreasing of kaolin ratio. Figure 6 shows linear shrinkage changed with changing in the ratio of addition (W.F).

There is a rise in (W.F) addition leads to a decreasing in the total linear shrinkage, kaolin produced liquid phase at high temperature at sintering process, which by surface tension in ceramic phase at solidification process.

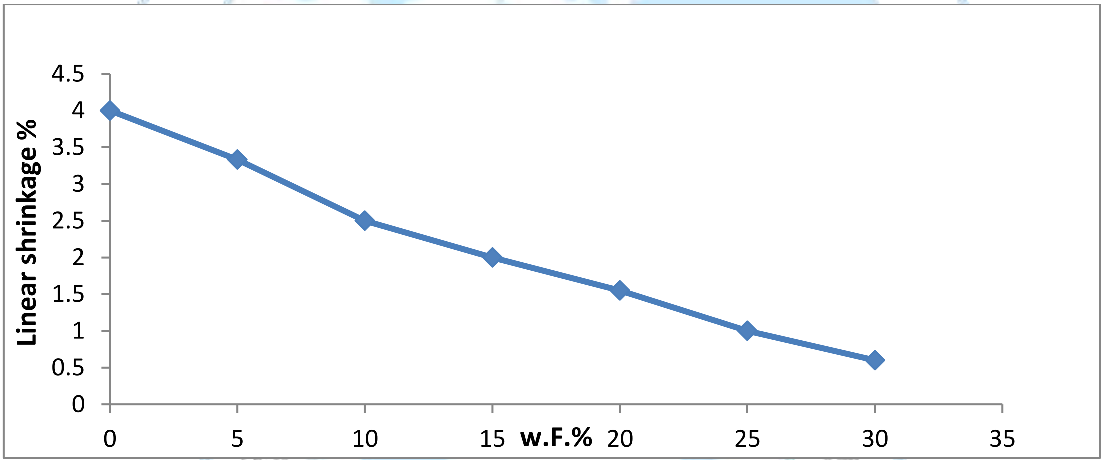

Figure 6: Relationship between L.SH and W.F%

Permeability

The permeability of water differs depending on the porous ratio, implying that the permeability of water is affected by porosity of the filter. It can be noted that the fabrication process of the ceramic filter does not obviously effects on the permeability values. Because, there are some other factors pronounced impact upon the permeability such as pore size distribution and pore volume of the ceramic filter [18]. Figure 7 shows the permeability change with changeing the apparent porosity and ratio of addition (W.F) %. The permeability of the filter increased with increasing porosity and (W.F) %, figure 7 [19].

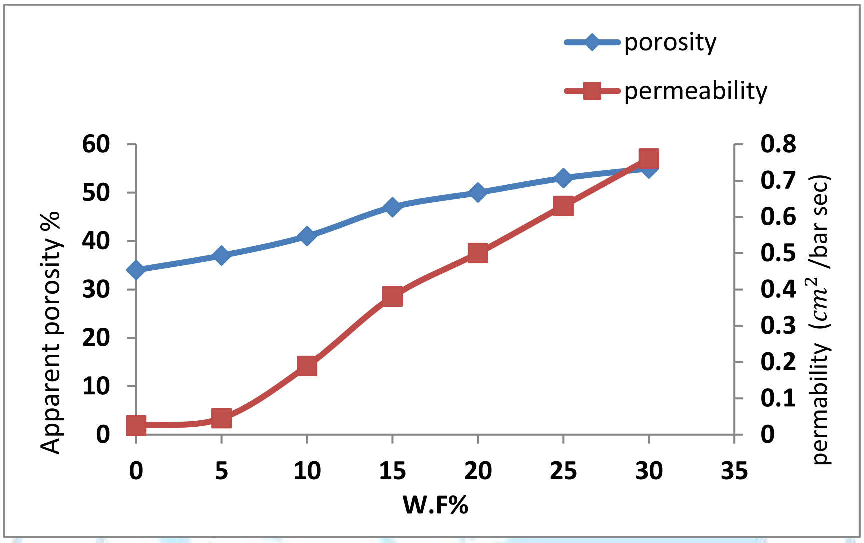

Figure 7 Relationship between Permeability and A.P%

Mechanical test

Compressive strength

Compressive strength effect with apparent porosity. The pores weaken the ceramic product mechanically, so increasing the apparent porosity leads to decreasing in mechanical properties. Therefore, it is very important to maintain the balance between the ratio of pores generated and the mechanical properties required in the filter.

Figure 8 shows the compressive strength changed with changing the ratio of addition (W.F) %. The compressive strength decreased with increasing of addition (W.F) because pores ratio increased that are formed, which leads to the reduction of the density and thus reduce compressive strength

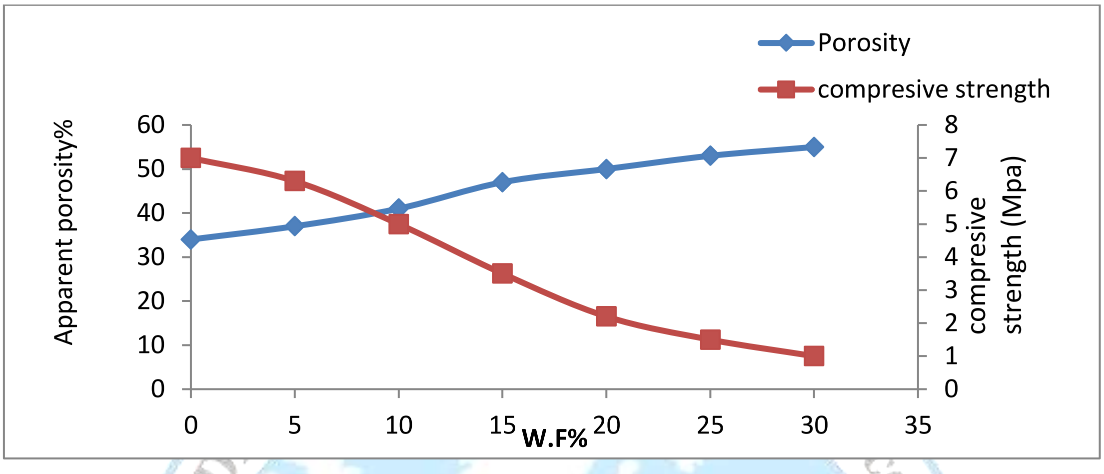

Figure 8: Relationship between C. S. and A.P%

Diametrical strength

Diametrical strength would be contingent with amount of pores present in the ceramic body. The (W.F) specimens produced lower diametrical strength, due to the formation of apparent porosity that effects on diametrical strength and reduce it. Figure 9 shows the diametrical strength change with change the ratio of addition (W.F) %. The diametrical strength decreased with increasing of addition (W.F) because pores increase that formed figure 9.

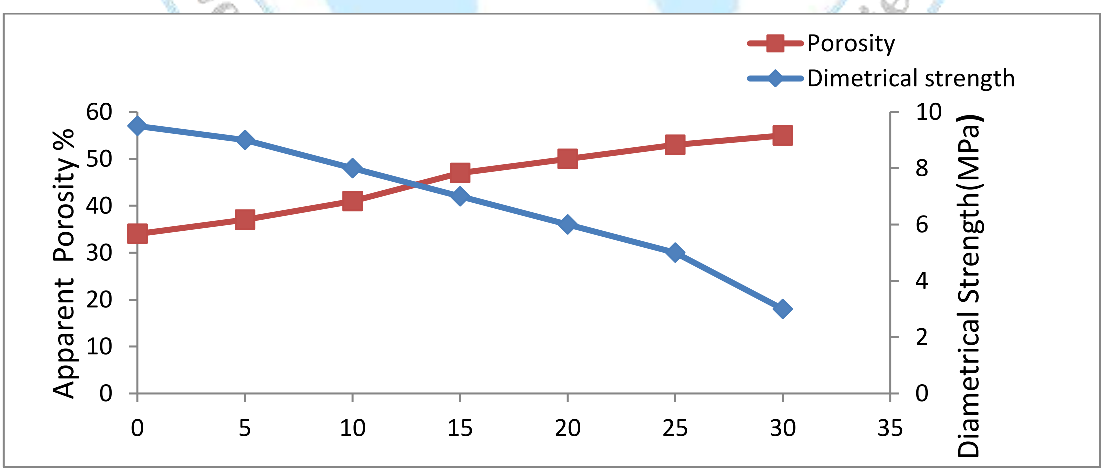

Figure 9: Relationship between D.S and A.P%

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Microstructure by using Scanning Electron Microscope (SEM)

Microstructures of the specimens were studied for cross-section of specimens as shown in figure10.

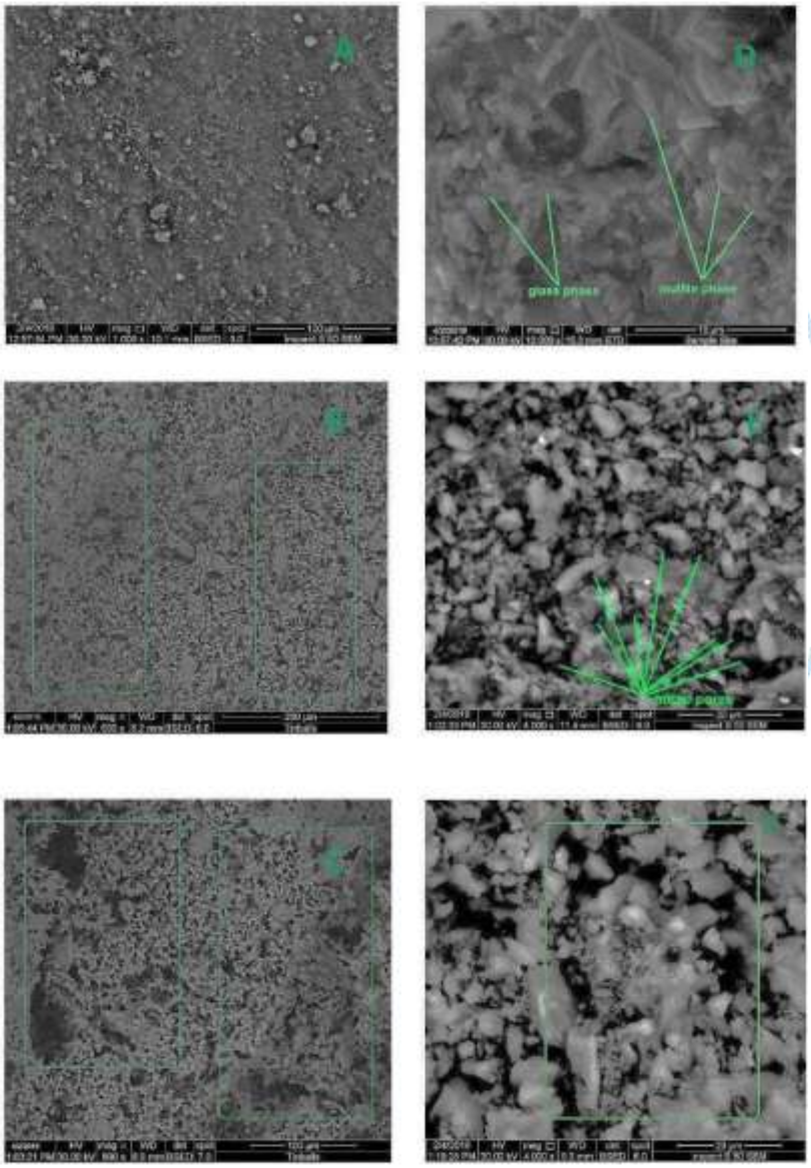

Figure 10: SEM image for filter Specimens cross-section surface:
A, D: filter with 0% W.F.
B, E: filter with 5% W.F.
C, F: filter with 30% W.F.

- Image A: the surface of the fracture is shown with very few pores. This pure mixture is composed of porcelanite only, without the addition of wheat Flakes. It is clear from the picture that there are a high glass phase and little mullite phase crystals.
- Image B: the surface of the fracture of 5% of the additives shown from the image is a high proportion of small micro pores and distributed homogeneously and uniform, these pores obtained with the addition ratio of 5% W.F.
- Image C: the surface of the fracture of 30% of the additives, the image shows large micro pores created from the connection of small micro pores with each other.
- Images A, B, C it can be Conclude that by adding 5% of the wheat Flakes, small unrelated micro pores were generated. When 30% of the wheat Flakes were added large continuous micro pores were produced which resulted in high porosity and thus high permeability. These pores form channels of water passage through the filter. The pictures appeared useful for water filters because increasing the porosity will increase the passage of water.
- Image D: the fracture surface of the pure mixture is shown but with a higher magnification than Figure A, it is clear that the filter consists of a mullite phase, a glassy phase and, a few pores.
- Image E: the fracture surface of 5% of the additive, The picture shows the generation of small micro-pores that are distributed regularly and include all the surface of the specimens and the high magnification shows that there is a connection between some small-micro pores.
- Image F: the fracture surface of 30% of the additive, the image shows but with a higher magnification than Figure C large micro pores created from the connection of small micro pores and These pores form channels of water passage through the filter.

Conclusion

water filter was prepared from a mixture (Porcelanite and Kaolin), the percentage of kaolin was 10% as binding materials with adding natural addition (W.F) with ratios (5,10,15,20,25 and30) %. So, the ceramic materials used in manufacture of the filters are of natural materials, environment friendly and harmless compared with other materials. The physical and mechanical properties were affected by the added ratio of (W.F). From the experimental work for this filter gave the following results

Apparent porosity of filter specimens is increased with increasing of the addition (W.F) %. The max ratio of porosity was (55%) with 30% of (W.F). Water absorption, Loos in mass and permeability increased with increasing (W.F) % the result show the max ratio of (loos in mass was 24.25%, water absorption was 50.99%, permeability was 0.131 (cm^2/bar.min) with 30% ratio of (W.F). linear shrinkage, apparent density, compressive strength, and diametrical strength decreased with increasing W.F%. The max ratio of L.SH was 0.6%, A.D was 1.07 (g/cm^3), C.S. was 1 (MPa) and D.S was 3 (MPa).

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