Firing Temperature and Duration Effects On Absorbency and Porosity of Pottery Tubes

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Abstract:-

The objective of this work is to manufacture a pottery tubes from local Iraqi materials without costs and test their porosity and absorbency for water filtering and reducing its turbidity. Thirty-six pottery tubes were manufactured under different production conditions namely: different fire duration (4 to 5 hours), and different firing temperature (850 °C to 1100 °C). Two sets of pottery tubes are manufactured, the first is non perforated tubes (model 1 or M1), and the second (M2) is perforated with 13 holes of (0.5 mm diameter) linearly arranged along their wall. Each model includes 18 tubes of 30 mm outer diameter, 4 mm wall thickness and 200 mm length. The results show that for model M1 the porosity for firing duration of 4 hrs are of range (48.21% to 42.85%) at firing temperature of range (850 °C to 1100 °C) respectively (i.e the porosity decreases with increasing firing temperature) .The same trend is obtained for model M2 ,as well as obtained for absorbency.

Key Words: Pottery, Absorbency, Porosity, Temperature, Firing

1.Introduction

Pottery was most of all known as traditional clays before 1950s. It really is regarded as the most traditional and manmade non-metallic materials made up of clay - plastic-type material, silica (quartz and fine sand) , nonplastic properties, and feldspar ($6SiO_2$, $CaO.Al_2O_3$. $6SiO_2$ $6SiO_2, K_2O.Al_2O_3$ and $Na_2O.Al_2O_3$.) , Fluxes or mineralizers as primary raw ingredients and it is solidified by firing at a higher temperature differing from 600 to 1400° C [10].

Permeable materials are currently utilized as a part of numerous applications, for example, last items and in different mechanical procedures. Microporous materials are utilized as a part of different structures and creations, for example, polymeric froths for bundling, aluminum light-weight structures in structures and planes, permeable stoneware for water decontamination. Certain permeable materials have extraordinary properties and capacities that can't typically be acquired by ordinary thick partners [7,11], and in addition filtration of particulates from diesel motor fumes gasses, and filtration of hot destructive gasses in different mechanical procedures [6,8]. Porosity is clearly alluring in light-weight items, warm protection, impetus bolsters, wicking and filtration employments.

Pottery as a permeable material property has both positive and negative perspectives. Negative viewpoints incorporate friability, loss of quality, undesirable liquid assimilation and so forth. Permeable clay materials comprise of no less than two stages: a pottery (strong) stage, and the for the most part gas-filled permeable stage. The gas substance of the pores for the most part modifies itself to the nature as an exchange of gas with the nature through pore channels. Shut pores can contain a gas arrangement that is of the environment .The pottery (grid) material can either be single stage or, as displayed as, multi-stage (e.g. one more crystalline stages and a glass stage). While indicating the porosity, a qualification should be made between open (available all things considered) porosity and shut porosity. Open porosity can be additionally arranged into open deadlock pores and open pore diverts as appeared in **Fig. 1.** Contingent upon the specific application, either a more open porosity (e.g. a channel component that should be penetrable) or a shut porosity (e.g. a thermal insulator) might be craved. The porosity level increments [6].

entirety of the open and shut porosity is alluded to as the aggregate porosity. On the off chance that the partial porosity of a material is generally low, at that point the shut porosity will command; as the fragmentary porosity builds, the open

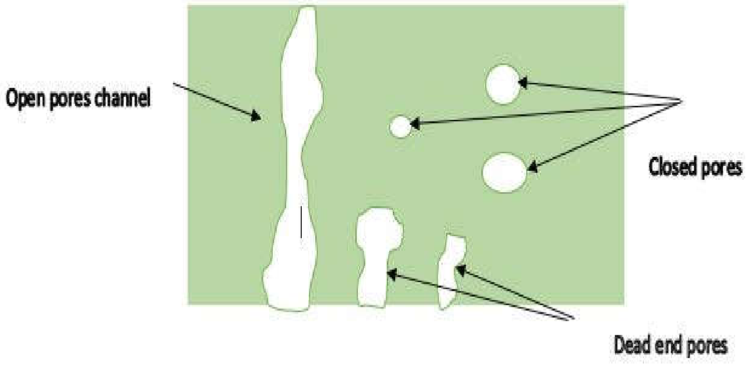


Fig. 1 Schematic of pore types Schulz [9]

Chen et al (2005) created permeable alumina tubes by the radial trim within the sight of a natural pore framing specialist. Alumina tubes are created utilizing two distinctive alumina powders with limit measure conveyance (AES-12 and TM-D). The trial comes about demonstrate that the TM-D powder is constrained to get the homogeneous structures and the AES-12 powder offers a decent adaptability in angle plan, reliant on the slurry character. **Studart (2006),** introduced the fundamental handling courses utilized for the manufacture of macroporous earthenware production with customized microstructure and substance structure. In our perspective, unique requests may emerge as the creation of froths that set at gentle temperatures and encompassing cools, the diminishment in the quantity of preparing steps, the utilization of just biocompatible and not-lethal reagents, the generation of permeable earthenware production that don't require consequent pyrolysis, calcination, and sintering, and clearly the decrease of costs required all the while. **Jatindra (2009)** exhibited concise audit about ceramic as a Potential Tool for Water Reclamation. A huge record of the water recovery capability of artistic is attracted which considerably adds to enhancing water quality. Joining and use of pottery as channel, large scale and microfilter, cross breed and composite layer channel, and adsorbent utilizing filtration, adsorption, assimilation and particle trade systems has opened another approach in the field of drinking water refinement, wastewater treatment, expulsion of amphibian contaminations, and de-eutrophication of water. The promising viability of various altered types of pottery in the cleansing and treatment of freshwater and wastewater would fundamentally add to giving natural, inorganic, and microbial risks free subjectively and quantitatively enhanced recycled water to our present and inevitable eras requiring little to no effort with no ecological negative effects

Due to having several significant properties, it may, therefore, be inferred that earthenware is a vital common asset that can be created through the waste reusing process and may be used as a potential tool for water reclamation.

The objective of this work is to manufacture a pottery tubes from local Iraqi materials and test their porosity and absorbency for water filtering and reducing its turbidity. Tubes were manufactured under different production conditions namely: different fire duration (4 to 5 hours), and different firing temperatures (850 °C to 1100 °C).

2. Raw Materials

Two main types of raw materials are available for producing local pottery. The red clay soil, which is available at Khan Beni Saad, north east of Baghdad. The red clay soil is well known and commonly used in the ceramic artist’s work. The kaolin is another clay soil type also used in art work but it needs a higher firing degree to mature, which is available as the purest red clay soil at Kraat- Baghdad. Samples of each type were analyzed by using x-ray fractions at the laboratories of the Iraqi State of Geological Survey. The composition of each type are given in **Table .1**. In this work the kaolin used in the production of potter pipes because the Silica, SiO_2, and Alumina, Al_2O_3, are higher in Kaolin than that of red clay soil and they represent the main components of pottery structure.

Table .1 X-Ray fractions analysis of clay soils composition.

Clay soil	Composition, %										
	SiO_2	Al_2O_3	Fe_2O_3	**CaO**	**MgO**	Na_2O	K_2O	SO_3	**Ti**O_2	**LOI**	**Total**
Red clay	**39.96**	**10.30**	**6.32**	**17.32**	**4.19**	**0.81**	**1.65**	**0.07**	-	**18.26**	**98.88**
Kaolin	**48.62**	**34.86**	**0.69**	**0.17**	**0.43**	**0.15**	**0.50**	**0.07**	**1.07**	**12.88**	**99.44**

3.Adding of Water

The methods that can be used for adding water to pottery mixtures are the wet method in which sufficient quantity of water is gradually added to make dough of pottery mixture. Water is continuously and gradually added with continuous and well mixing. The mixture was stored in labeled plastic bag at least for 24h in a cold place to prevent water evaporation and to maintain uniform moisture distribution throughout the mixture. **Fig. 2** shows the stages of preparation of the pottery mixture

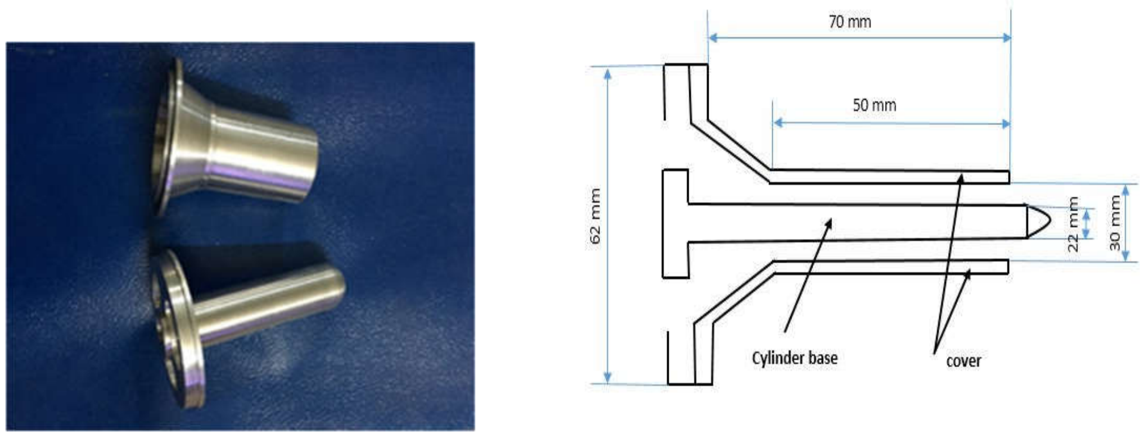
4.The Molds

Two sets of pottery tubes were produced with specific dimensions. The first set was used kaolin clay without shape change. These groups of filtration modules were coded as **M1.** The second set of pottery tubes was used kaolin clay with thirteen hole arranged in line These groups of filtration modules were coded as **M2**. The first and second sets are of 30 mm in out diameter with 4 mm a thickness and 200mm length. A 0.5mm thirteen holes are arranged in line for the second set. Aluminum molds of two parts, cylindrical were used to base and its cover form the ceramic filter tubes, as shown in **Fig. 3**. The base of the mold contains a groove for extrusion process (Extrusion is a process used to create objects of cross-sectional profile, a material is pushed through the desired cross-section). It is used to hold the pressed material inside the mold. The cover is used to produce pottery tubes.

a) Clay from river side

b) Clay after adding water (as a dough)

Fig. 2 Shows the stages of preparation of the pottery mixture.



a) Aluminum molds of two parts

b) Sectional view of molds

Fig. 3 Two main parts of the mold, the cylinder base, and the cover.

5.Firing Temperatures

Carbolite Furnace of a maximum temperature of 1200 °C with good ventilation was used for firing the formed pottery tubes, Figure 4 shows the kiln burning chamber of 300 mm in depth, 190 mm in width, and with a height of 150 mm. Thirty-six pottery tubes of 30 mm outer diameter were placed in the kiln chamber to produce the pottery tubes shown in **Fig 5**. Different final degrees of firing were tested, these are 850,900,950,1000,1050 and 1100 °C. The final temperature is reached by increasing kiln temperature in stages as shown in **Table 2**. After reaching the final temperature, the samples were left in the kiln for 24hr. The kiln door was then opened gradually until it reached the room temperature to prevent cracks. The pottery porous tubes were produced depending on firing temperature and duration effects, as discussed in the results.

Fig. 4 Kiln furnace used for firing pottery tubes.

Table .2 Pottery drying time and firing time schedule

Stage	The operation	Time (min)	Temperature (°C)
1	**Drying**	**120**	**70**
2	**Firing**	**15**	**200**
3	**Firing**	**15**	**400**
4	**Firing**	**30**	**600**
5	**Firing**	**60 or 90 or 120**	**850 or 900 or 950 or 1000 or 1050 or 1100**

(a) Pipe production after the extrusion process.

(b) After the drying process.

(c) After different firing temperature and duration effects.

Fig. 5 Pottery tubes.

6. Porosity measurement

Porosity is a measure of the voids in a material, and is a small amount of the volume of voids over the aggregate volume its range is in the vicinity of 0 and 1, or as a rate of 0 and 100%. A few strategies can be utilized to quantify porosity:

1. Direct technique is calculating the pore volume of the permeable specimen, and after that deciding the volume of the skeletal material without any pores [3]
2. Optical technique is figuring the range of the material versus the territory of the pores appear under the magnifying lens. The "areal" and " volumetric " porosities are equivalent for permeable media with arbitrary structure [4].
3. Water immersion technique is figuring pore volume level with add up to volume of water subtract volume of water left in the wake of dousing [3].
4. Water evaporation technique is calculating pore volume equal mass of saturated sample subtract mass of dried sample.

Then result will be divided on density of water. The Absorbency is calculated as [1].

$$\text{Absorbency}=\frac{m_2-m_1}{m_1}x100 \quad (1)$$

The porosity (ϕ) is calculated as

$$\phi=\frac{pore\ volume}{total\ volume}x100 \quad (2)$$

This method used in present work.

5. Gas extension technique utilized example of known volume is encased in a holder of known volume. It is associated with another holder with a known volume which is cleared (i.e., close vacuum pressure). At the point when a valve associating the two holders is opened, gas goes from the principal compartment to the second until the point that a uniform pressure circulation is accomplished. Utilizing perfect gas law , the volume of the pores is figured as [3]

$$V_V=V_T-V_a-V_b\frac{P_2}{P_2-P_1} \quad (3)$$

The porosity is evaluated as:

$$\phi=V_V/V_T \quad (4)$$

Note that this technique expect that gas conveys between the pores and the encompassing volume. Practically speaking, this implies the pores must not be shut cavities.

6. Computed tomography technique utilizing modern CT checking to make a 3D rendering of outside and inner geometry, including voids [6]. At that point perform investigation utilizing PC programming

7. Results and Discussions

Pottery tubes are manufactured from local materials and their Absorbency and porosity are tested in this work. Thirty-six pottery tubes were produced under different production condition. The production condition includes the use of different fire duration and firing temperature. The results of calculations for dry mass, wet mass under different production condition. **Fig .6** shows the change of dry mass and wet mass for two model (M1, M2) with firing temperature extended for four hours from drying and incineration. This figure shows the dry mass is 96 grams and the wet mass is 123 grams for M1, while that for M2 is 90 grams and 115 grams respectively at firing temperature of 850 °C. The percentage dry mass decreases are 0%, 1.04%, 1.04%, 3.125%, and 4.166% at firing temperature of 900 °C, 950 °C, 1000 °C, 1050 °C, and 1100 °C, respectively for M1, but for wet mass are 0%, 1.62%, 1.62%, 4.06%, and 5.69% for M1. Also the percentage decreases in the dry mass are 1.11%, 1.11%, 2.22%, 2.22%, and 3.33% at the same firing temperature for M2. But the percentage decreases in the wet mass are 2.6%, 2.6%, 4.347%, 4.347%, and 6.08% for M2.

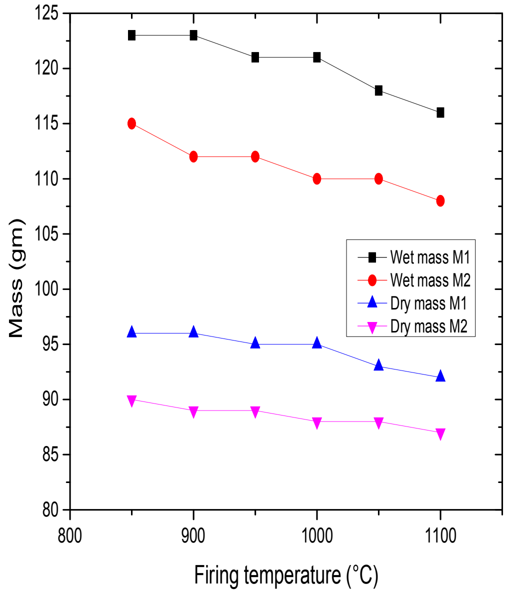


Fig. 6 Dry mass and wet mass for models (M1, M2) versus firing temperature for four hours from drying and incineration

Fig.7 shows the dry mass and wet mass change for two models (M1, M2) versus firing temperature through four and half hours from drying and incineration. The dry mass is 95 grams and the wet mass is 120 grams for M1, while that for M2 is 89 grams and the wet weight is 112 grams at firing temperature of 850 °C.

Table.3 shows the percentage decreases in the dry mass. But **Table. 4** shows the percentage decreases in the wet mass at different firing temperature

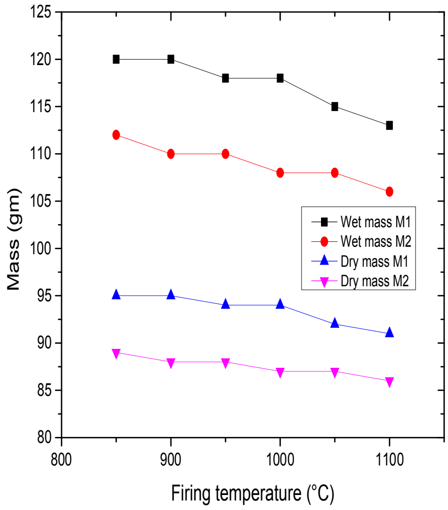


Fig. 7 Dry mass and wet mass for two models (M1, M2) versus firing temperature through four and half hours from drying and incineration

Table .3 Percentage dry mass decrease (4.5 hrs. fire duration)

Temperature	**900 °C**	**950 °C**	**1000 °C**	**1050 °C**	**1100 °C**
Model M1	0%	1.052%	1.052%	3.157%	4.21%
Model M2	1.123%	1.123%	2.247%	2.247%	3.37%

Table .4 Percentage wet mass decrease (4.5 hrs. fire duration)

Temperature	**900 °C**	**950 °C**	**1000 °C**	**1050 °C**	**1100 °C**
Model M1	0%	1.66%	1.66%	4.166%	5.833%
Model M2	1.785%	1.785%	3.57%	3.57%	5.35%

Fig.8 shows the dry mass and wet mass change for two models (M1, M2) versus firing temperature through five hours from drying and

incineration. The dry mass is 95 grams and the wet weight is 120 grams for M1, while that for M2 is 88 grams and the wet weight is 110 grams at firing temperature of 850 °C. **Table.5** show the percentage decreases in the dry mass. But **Table.6** show the percentage decreases in the wet mass at different firing temperature.

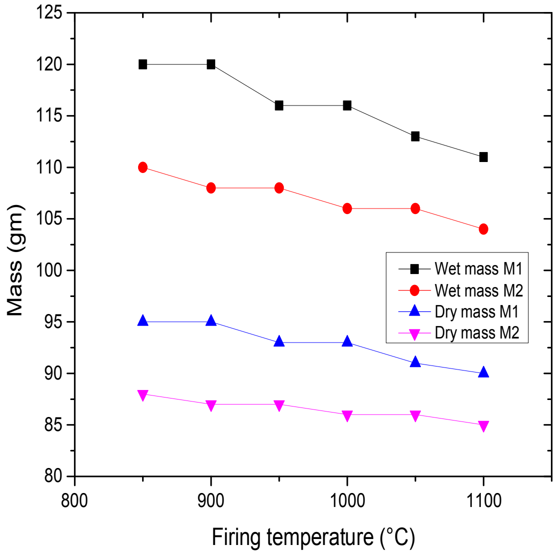


Fig. 8 Dry mass and wet mass for two model (M1, M2) versus firing temperature through five hours from drying and incineration

Table .5 Percentage dry mass decrease (5 hrs. fire duration)

Temperature	900 °C	950 °C	1000 °C	1050 °C	1100 °C
Model M1	0%	2.105%	2.105%	4.21%	5.26%
Model M2	1.136%	1.136%	2.272%	2.272%	3.409%

Table .6 Percentage wet mass decrease (5 hrs. fire duration)

Temperature	900 °C	950 °C	1000 °C	1050 °C	1100 °C
Model M1	0%	3.33%	3.33%	5.83%	7.5%
Model M2	1.81%	1.81%	3.63%	3.63%	5.45%

Figures (9) to (11) present Absorbency behavior for two models (M1, M2) versus firing temperature through 4 to 5 hours from drying and incineration. The decreases in the Absorbency with increase firing temperature and increase fire duration are given in **Table.7** Because increased firing temperature led to decreases core volume in kaolin.

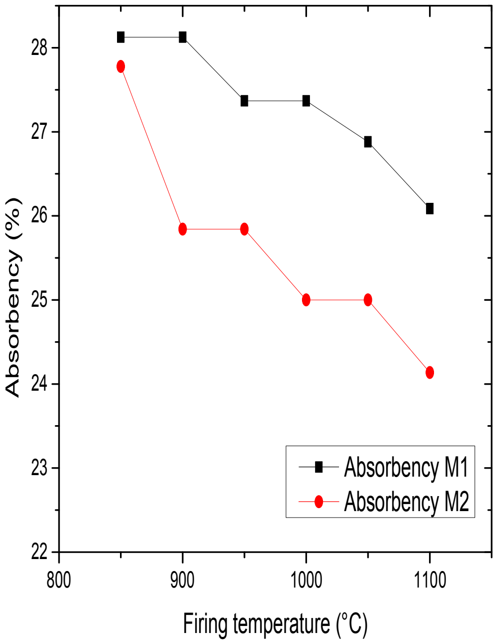


Fig. 9 Absorbency for two models (M1, M2) versus firing temperature through four hours from drying and incineration

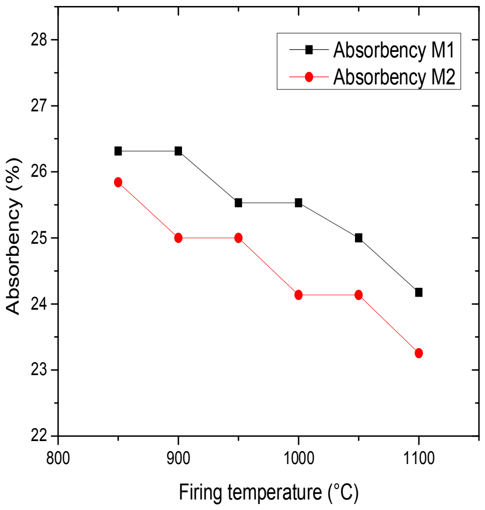


Fig. 10 Absorbency for two models (M1, M2) versus firing temperature through four and half hours from drying and incineration

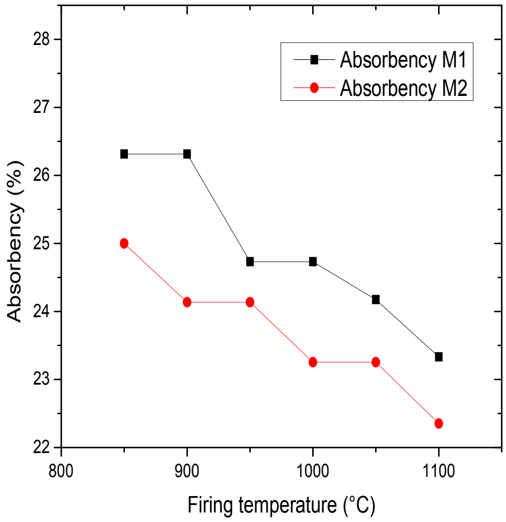


Fig. 11 Absorbency for two models (M1, M2) versus firing temperature through five hours from drying and incineration

Table .7 Absorbency for two models (M1, M2)

Temp.	**Absorbency**					
	4 hrs. fire duration		4.5 hrs. fire duration		5 hrs. fire duration	
	M1	M2	M1	M2	M1	M2
850 °C	28.125 %	27.777 %	26.315 %	25.842 %	26.315 %	25 %
900 °C	28.125 %	25.842 %	26.315 %	25 %	26.315 %,	24.137 %
950 °C	27.368 %	25.842 %	25.531 %	25 %	24.731 %	24.137 %
1000 °C	27.368 %	25 %	25.531 %	24.137 %	24.731 %	23.255 %
1050 °C	26.881 %	25 %	25 %	24.137 %	24.175 %	23.255 %
1100 °C	26.086 %	24.137 %	24.175 %	23.255 %	23.333 %	22.352 %

Figures (12) to (14) present Porosity behavior for two models (M1, M2) versus firing temperature through 4 to 5 hours from drying and incineration. The decreases in the Porosity with increase firing temperature and increase fire duration are given in **Table 8**. Because increased firing temperature led to decreases core volume in kaolin.

It was found that the absorbance and porosity in model M1 is higher than the model M2. This is due to the lower core volume in model M2 due to the presence of holes in tube.

Finally, the best firing conditions for pottery tubes are 1100 °C extended for five hours from drying and incineration, which agrees with Standard Iraqi No. 24/1988.

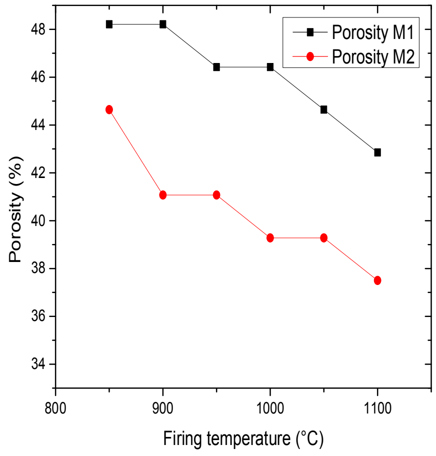


Fig. 12 Porosity for two models (M1, M2) versus firing temperature through four hours from drying and incineration

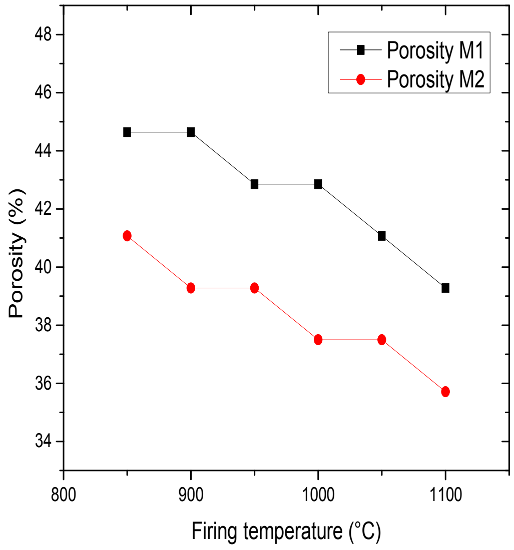


Fig. 13 Porosity for two models (M1, M2) versus firing temperature through four and half hours from drying and incineration

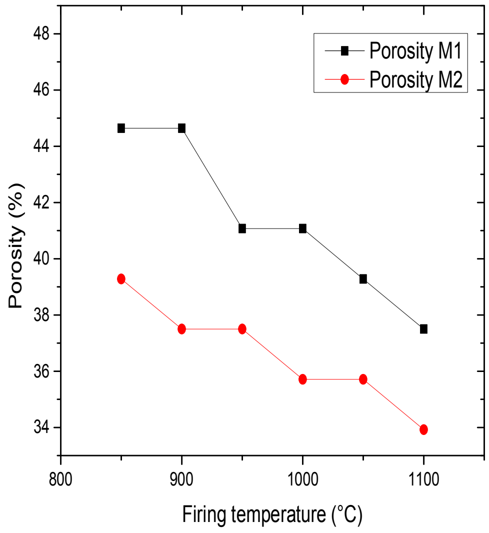


Fig. 14 Porosity for two models (M1, M2) versus firing temperature through five hours from drying and incineration

Table .8 Porosity for two models (M1, M2)

Temp.	**Porosity**					
	4 hrs. fire duration		4.5 hrs. fire duration		5 hrs. fire duration	
	M1	M2	M1	M2	M1	M2
850 °C	48.21 %	44.64 %	44.64 %	41.07 %	44.64 %	39.28 %
900 °C	48.21 %	41.07 %	44.64 %	39.28 %	44.64 %	37.5 %
950 °C	46.42 %	41.07 %	42.85 %	39.28 %	41.07 %	37.5 %
1000 °C	46.42 %	39.28 %,	42.85 %	37.5 %	41.07 %	35.71 %,
1050 °C	44.64 %	39.28 %	41.07 %	37.5 %	39.28 %	35.71 %
1100 °C	42.85 %	37.5 %	39.28 %	35.71 %	37.5 %	33.92 %

8.Conclusions

Production of pipes from local materials Iraqi without costs using extrusion principle is not recorded previously. The material used is clay from side of the Tigris river without adding any other material to produce hollow pipes with a porous wall. The contribution of this work is using of cheap materials available in nature to produce hollow pipes and study porosity and absorbency of those pipes to use them in elimination of water turbidity or production of fresh water or use them as a step in sewage water treatment. The following main conclusions can be extracted from previous discussions:

1. The pottery tubes mass decreases with increase firing temperature.
2. The best firing temperature is 1100 °C and the best duration

is five hours from drying and incineration for pottery tubes.

3. The porosity and Absorbency of pottery tube decreases with increase firing temperature.

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Nomencleature:

Symbols

V_V	effective volume of the pores $[m^3]$
V_T	volume of the sample $[m^3]$
V_a	volume of the holder encased the specimen $[m^3]$
V_b	volume of the evacuated container $[m^3]$
P_1	Initial pressure [Pa]
P_2	Final pressure [Pa]
m_2	mass of saturated sample [gm]
m_1	mass of dried sample [gm]

Greek letters

ϕ	porosity [%]

تأثير درجة حرارة الحرق والمدة على الامتصاصية والمسامية من أنابيب الفخار

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الخلاصة:-

الهدف من هذا العمل هو تصنيع أنابيب الفخار من المواد العراقية المحلية دون تكاليف واختبار مسامتها وامتصاصية لتصفية المياه والحد من تعكر. تم تصنيع 36 أنبوب فخار في ظروف إنتاج مختلفة وهي: مدة حرق مختلفة (4 إلى 5 ساعات)، ودرجة حرارة حرق مختلفة (850 درجة مئوية إلى 1100 درجة مئوية). تم تصنيع مجموعتين من أنابيب الفخار، الأول هو أنابيب غير مثقبة (نموذج 1 أو (M1)، والثاني ((M2مثقب مع 13 ثقوب من (0.5 مم قطر) مرتبة خطيا على طول جدارها. يتضمن كل نموذج 18 أنابيب قطرها الخارجي 30 مم، 4 مم سمك الجدار وطول 200 ملم. وأظهرت النتائج أن المسامية عند حرق لمدة 4 ساعات تتراوح بين (48.21٪ إلى 42.85٪) عند درجة حرارة حرق

من 850 درجة مئوية إلى 1100 درجة مئوية على التوالي (أي المسامية تنخفض مع زيادة درجة حرارة حرق) ، ويتم الحصول على نفس الاتجاه لنموذج M2، وكذلك الامتصاصية.

الكلمات الرئيسية: الفخار، الامتصاص، المسامية، درجة الحرارة، حرق