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FILTRATION OF CERAMIC SLUDGE – A CASE STUDY

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ABSTRACT

The following paper deals with investigating the parameters associated with the filtration of ceramic sludge produced in an Egyptian factory producing ceramic tiles. The slurry was filtered using a Buchner funnel fitted with canvas filter medium under five different absolute pressures. The average specific cake resistance and the filter medium were obtained each time. Calculations revealed that the cake was slightly compressible and that the filter medium resistance was independent of the prevailing pressure. From factory data, it was possible to evaluate the required filtration area for disposing of the sludge cake.

KEYWORDS: Filtration, ceramic, sludge, compressibility

1. INTRODUCTION

The management of ceramic sludge, often referred to as ceramic wastewater, has been the subject of very few studies. As early as 1991, this waste is used in the mixing process of ground raw materials diluted with water [1]. Thickening of the sludge by adding proper coagulants was tried [2-3]. In either case, the presence of coagulants in the thickened sludge prevent its recycling to the raw materials mixing tank thus resulting in material losses. In this respect, filtration is an alternative treatment that allows for recycling both clear water filtrate and deposited cake. One problem associated with investigating the filtration characteristics is that the behavior of the waste slurry flows a Bingham behavior [4]. Although the flow of Bingham fluids through porous media has been extensively studied [5 - 8], the specific filtration

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operation was only researched for incompressible cakes [9]. The recent work [10] points out to the possibility of treating Bingham fluids of low yield stress as Newtonian, which is the case in the current case [3].

In the present study wastewater ceramic sludge was filtered under different pressure differentials using canvas filter medium and the specific cake resistance and filter medium resistance determined as function of pressure. Using factory data, it was possible to evaluate the required area of filtration.

2. MATERIALS AND METHODS

2.2 Sludge Samples

The sludge samples employed for the experiments were kindly supplied by a ceramic tile plant located in Al Sharkia Governorate, Lower Egypt.

2.2 Experimental Setup

Filtration experiments were carried out by applying vacuum on the slurry in a Buchner funnel of 100 mm diameter. The absolute pressure was measured using a simple vacuum pressure gauge. Pressure fluctuations were within ± 5% of the gauge readings. The pressures investigated ranged from 100 mm water to 750 mm water. These were converted to Pa by considering the density of suspension to be 1055 $kg.m^{-3}$ as will be shown in section (3.1). The filtrate was collected at the following time intervals in a graduated cylinder: 2, 4, 6, 12 and 18 minutes.

At all times, the prevailing temperature was recorded and found to be 26±2^{o}C throughout the duration of experiments.

2.3 Method of Calculation

The determination of filter cake and filter medium characteristics was performed following the method [11]. This is briefly described in what follows:

If a volume of filtrate V is collected during time t, then the relation between these two variables takes the form:

$$t = \frac{\alpha\mu c}{2A^2\,\Delta p} V^2 + \frac{\mu R_m}{A\Delta p} V \qquad (1)$$

Where, μ is the filtrate viscosity (Pa)

c is the solid concentration in wastewater ($kg.m^{-3}$)

A is the area of filtration (m^2)

Δp is the pressure differential (Pa)

α is the average specific cake resistance ($m.kg^{-1}$)

R_m is the filter medium resistance (m^{-1})

The previous equation can be written in the form:

$$t = K\ V^2 + B\ V \tag{2}$$

Where the constants K and B are defined by Eq. (1).

This equation can be rearranged to read:

$$\frac{t}{V} = K.V + B \tag{3}$$

Hence a plot of $\frac{t}{V}$ against V should produce a straight line of slope K and intercept B, from which the average specific cake resistance (α) and the filter medium resistance (R_m) can be deduced.

On the other hand, the specific cake resistance varies with the pressure differential according to the empirical rule:

$$\alpha = \alpha_0\ \Delta p^s \tag{4}$$

Where α_0 is an empirical constant and (s) a characteristic of cake known as the compressibility coefficient of the cake.

3. RESULTS AND DISCUSSION

3.1 Properties of Wastewater Sludge

100 g of the wastewater slurry was evaporated and the solid residue weighed. This disclosed that the solid concentration in sludge = 152.8 $g.L^{-1} \equiv 152.8\ kg.m^{-3}$.

The average density of slurry was calculated as 1055 $kg.m^{-3}$.

The filtrate was considered to be pure water of density = 10^3 $kg.m^{-3}$ and of viscosity = 10^{-3} Pa.s.

The filtration area of the 100 mm diameter filter medium was calculated to be 0.007854 m^2

3.2 Volume – Time Curves

Figure 1 illustrates the relation between collected filtrate volume and time. As expected, higher pressures will increase the rate of filtration, resulting in collecting larger volumes during the same time period.

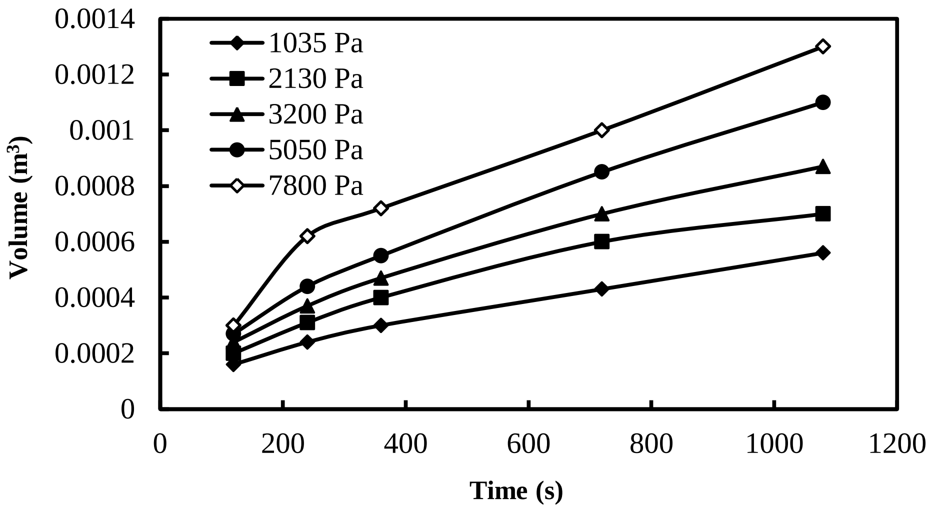

Fig. 1. Dependence of collected filtrate volume on time.

Using the volume – time data from Fig. 1 plots of t/V against volume were performed. The results are illustrated in Fig. 2. Straight lines of different slopes are obtained. Out of these slopes it was possible to calculate the values of average specific cake resistance α at each pressure differential. Also, intercepts of these lines allow for calculating the filter medium resistance.

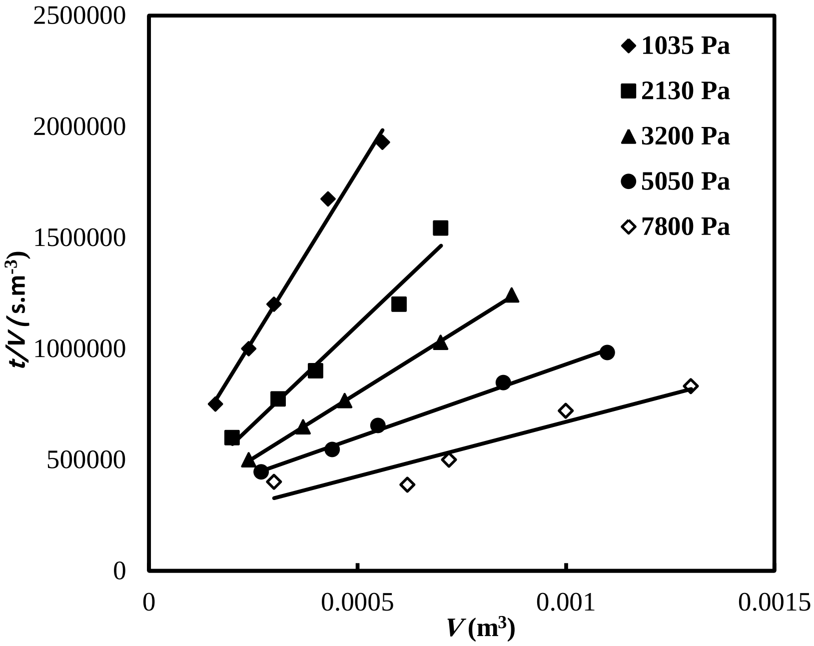

Fig 2. Linear plots of *t*/*V* vs *V*.

3.3 Rate of Filtration

The rate of filtration is defined as $\frac{dV}{dt}$ and can be obtained from the slopes of tangent lines to the curves in Fig 1. However, a more accurate way is to differentiate Eq. (1) with respect to time to obtain the following expression for $\frac{dV}{dt}$:

$$\frac{dV}{dt} = \frac{1}{2K.V+B} \tag{5}$$

This allows plotting the values $\frac{dV}{dt}$ of against filtration time at different pressures. The curves shown in Fig. 3 clearly disclose a decrease in rate with filtration time and an increase with increases pressure.

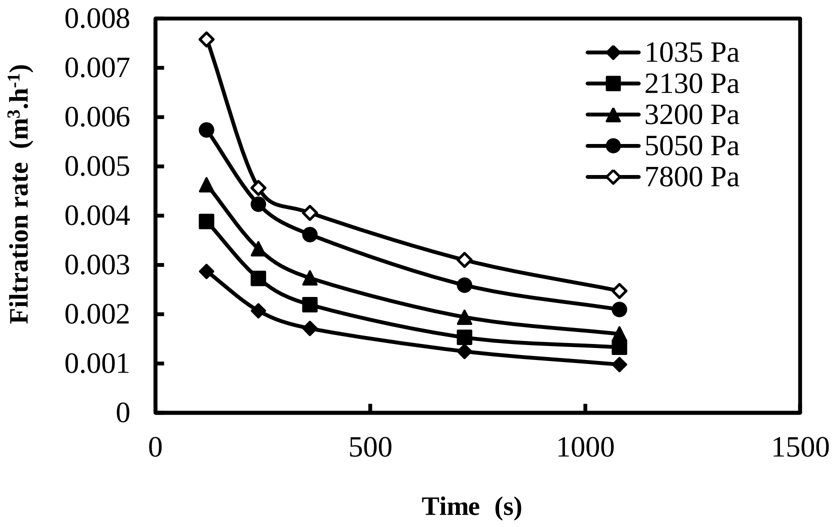

Fig. 3. Variation of filtration rate with time and pressure.

On the other hand, the overall filtration rate is defined as $\frac{V_{total}}{t_{total}}$ and its increase with pressure can be followed from Fig. 4.

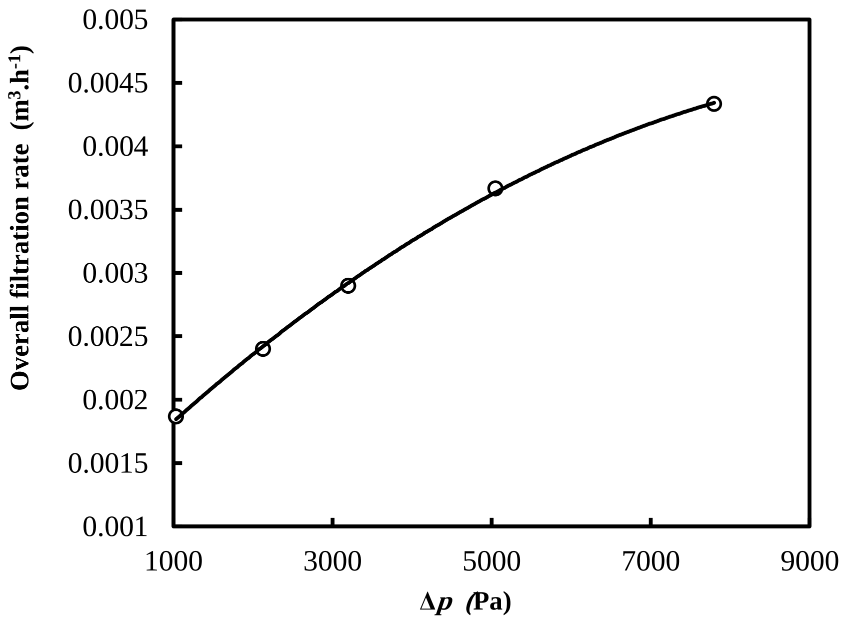

Fig. 4. Variation of overall filtration rate with pressure.

3.4 Compressibility of the Cake

The cake compressibility is obtained from Eq. (4) by taking the logarithms of both sides:

$$log\alpha = log\alpha_{\circ} + s.log\Delta p \qquad (6)$$

Figure 5 shows the straight line obtained on plotting log α against log Δp. The slope of that line represents the compressibility coefficient s of the cake. This value was found to equal 0.26. This denotes weak compressibility of the cake as (s) normally ranges from 0.2 (cakes of low compressibility) to reach 0.8 for highly compressible sludge [11]. This result is expected in view of the nature of the species constituting the solid component of the cake. This mix contains large proportions of non-plastic quartz and feldspar with lower amounts of plastic clay [12]. Also, the value of α_0 was calculated as 2.15×10^{8} $m.kg^{-1}.Pa^{-0.26}$

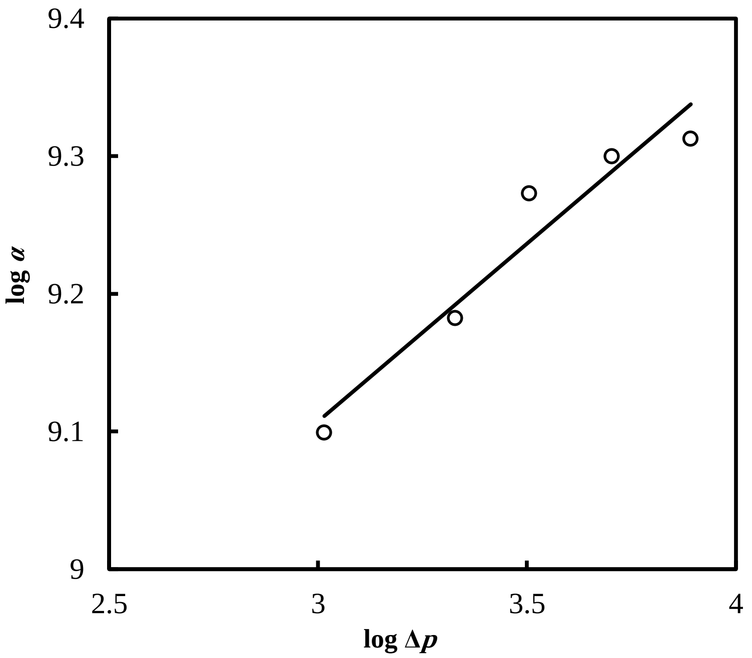

Fig. 5. Effect of pressure on specific cake resistance.

On the other hand, Fig. 6 reveals that the filter medium resistance is practically independent of pressure differentials. The average value of this resistance = 233300 m^{-1}.

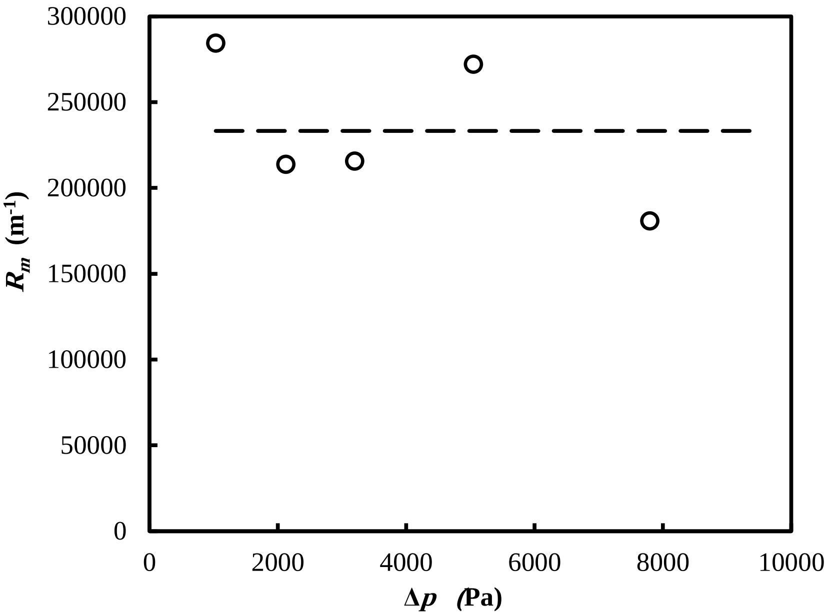

Fig. 6. Effect of pressure on filter medium resistance.

3.5 Filtrate Retained in Cake

The cake remaining after filtration obviously contains a certain amount of liquid filtrate. This was determined after each filtration run by weighing the wet cake and leave it to dry at 110°C in a drying oven for 2 hours. It was then reweighed and the percent filtrate retained estimated using the expression:

$$\% \text{ Liquid retained} = \frac{W_{wet} - W_{dry}}{W_{wet}} \times 100\% \qquad (7)$$

As expected, increasing the pressure differential Δp resulted in decreasing the amount of liquid retained in cake voids as evidenced from Fig. 7.

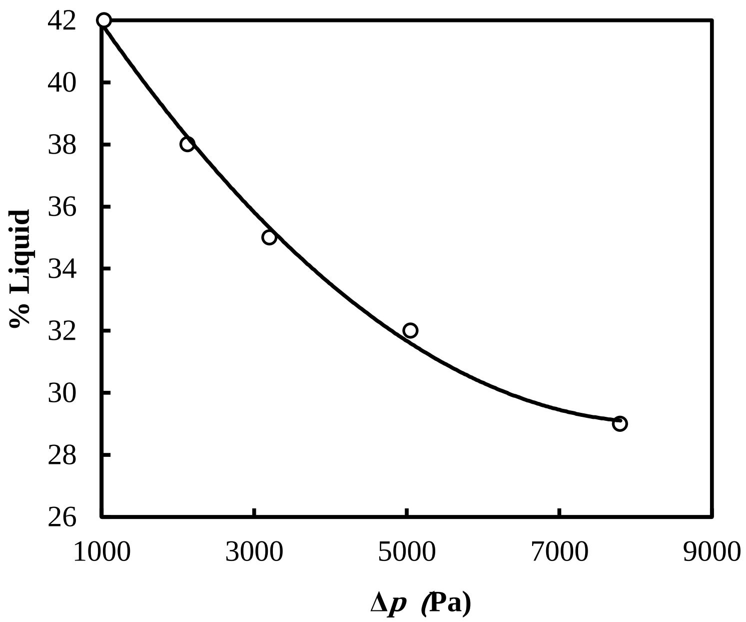

Fig. 7. Effect of pressure on percent filtrate retained in cake.

3.6 Estimation of Filtration Area

If the weekly amount of solid sludge produced by the factory is to be recovered from its suspension by filtration, then it is necessary to estimate the required filtration area based on the above parameters. According to factory data, a filtrate volume of about 35 m^3 is produced that has to be filtered in a maximum of 4 hours. A filtration pressure of 15 kPa was also assumed.

Substituting in Eq. (4) with the obtained values of α_0 and s, we write:

$$\alpha = 2.15\times10^8\ \Delta p^{0.26}$$

For a pressure differential Δp = 15000 Pa, the value of $\alpha = 2.62\times10^9$ $m.kg^{-1}$ Assuming the filter medium resistance to be pressure independent ≈ 233300 m^{-1}, and substituting with the factory data in equation (1), we get:

$$4\times3600 = \frac{2.62\times10^9\times10^{-3}\times152.8}{2A^2\times15000}\times35^2 + \frac{10^{-3}\times233300}{A\times15000}\times35$$

Solving for A^{-1} we get $A^{-1} \approx 0.03$ m^{-2}, hence $A \approx 33$ m^2.

4. CONCLUSIONS

Filtration of wastewater sludge from a ceramic tile factory was performed in a series of experiments to determine filtration parameters. The effect of pressure on filtrate volume collected at different time periods was revealed and the results used to calculate the compressibility coefficient of the cake. The value 0.26 obtained for this parameter proves that the cake is slightly compressible. The calculated values of filtration parameters allowed for estimating the filtration area required to process the expected throughput of sludge waste.

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ترشيح حمأة السيراميك

يدرس البحث العوامل المرتبطة بترشيح حمأة السيراميك الناتجة من مصنع لبلاط السيراميك حيث تم ترشيح المعلق باستخدام مرشح بوخنر ووسط ترشيح من الكانفس (قماش خيمة) وذلك تحت خمسة فروق مختلفة من الضغط، وتم تحديد التركيز الوزنى للمادة الصلبة الموجودة بالحمأة ووجد أنه يساوى ١٥٢.٨ كجم لكل متر مكعب وتم من خلال النتائج استنتاج قيمة متوسط المقاومة النوعية للمادة الصلبة الناتجة من الترشيح ومقاومة وسط الترشيح وقد ظهر أن راسب الترشيح له معامل انضغاط منخفض نسبيا (٠.٢٨) وتم تفسير ذلك على ضوء تركيب الحمأة الغنية بالسيليكا و الفلسبار غير القابلين الآنضغاط، وأن مقاومة وسط الترشيح تكاد تكون غير معتمدة على الضغط المحدث، هذا وقد امكن باستخدام بيانات المصنع تقدير مساحة الترشيح اللازمة للتعامل مع هذه الحمأة على أساس أن كمية الحمأة المتكونة بالمصنع إسبوعيا تساوى حوالى ٣٥ متر مكعب يفترض ترشيحها خلال أربع ساعات.