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Determination Of Mechanical, Thermo-Physical And Filtration Properties Of Dried Clay Mixtures Of Different Sand Concentrations For Water Storage Vessel

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ABSTRACT: The study experimentally investigated the crushing strength, thermal conductivity and filtration properties of dried clay mixtures of different sand concentration, using clay sample from Isan-Ekiti, after experimental comparison with clay sample from Igbara-Odo, both in Ekiti State, Nigeria. The percentage by weight of sand considered are from 0% (increasing progressively by 10%) to 100%. 50g, 200g and 250g of clay sample composition were mixed with the various percentage by weight of sand using clean water to form the crushing, thermo-physical and water filtration specimens respectively. Tensometer, Lee's disc apparatus and Calibrated beaker of 600ml capacity were used to determine the crushing strength, thermal conductivity and filtration rate of the specimens respectively. The result shows that crushing strength of the specimens was found to decrease with increase in percentage weight of sand from 7.28MN/m^2 to 1.53MN/m^2 respectively. However, thermal conductivity of the specimens was observed to increase with increase in percentage weight of sand from 0.0133Wm^{-1}k^{-1} to 0.1191Wm^{-1}k^{-1} respectively. Also, filtration rate of the clay sand specimens was found to increase with increase in percentage weight of sand concentration from 0.00422cm^{3}s^{-1} to 0.01449cm^{3}s^{-1} respectively. In a similar trend, the permeability of the specimens increases with increase in percentage of sand concentration from 0.0017darcy to 0.003darcy respectively. It is observed that the clay-sand mixture specimen with 0% weight of sand has the highest crushing strength, least thermal conductivity, least filtration rate and least permeability, which will be the ideal specimen for making water storage vessels (provided it is oven fired instead of sun-dried).

KEY WORDS: Mechanical properties, Thermo-physical properties, Filtration properties, Dried clay mixtures, Sand concentrations, Water storage vessel, Isan-Ekiti

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1. INTRODUCTION

Clay is a general term including many combinations of one or more clay minerals with traces of metal oxides and organic matter. Clays exhibit plasticity when mixed with water in certain proportions. When dry, clay becomes firm and when fired in a kiln, permanent physical and chemical changes occur. These reactions, among other changes, cause the clay to be converted into a ceramic material. Because of these properties, clay is used for making pottery items, both utilitarian and decorative, and construction products, such as bricks, wall and floor tiles. Different types of clay, when used with different minerals and firing conditions, are used to produce earthenware, stoneware, and porcelain [1]. A lot of research study had been carried out to investigate the properties, uses and applications of clay. Muawia [2] investigated the reliability of using the direct shear test for different clay contents and different moisture contents using an adequate shearing strain. His result shows that the cohesion of the mixture was found to increase consistently with the increase of clay content. Also, increase in moisture content was found to cause a drop in both cohesion and angle of internal friction. These changes are not independent of the density state of clay-sand mixture. Ihom et al., [3] investigated the impact of swelling indices of sokoto clays on the moulding properties of the clays in sand mixtures. They sampled four clays (labelled A, B, C, and D) from different locations in sokoto state of Nigeria. The analysis of their result revealed that clay B has the highest green and dry compression strength value of 71.7kN/m^2 and 3225.75kN/m^2 respectively. Also, their findings show that clay B has the highest smelling index of 60% and very high degree of expansiveness when compared to the other clays. Sedat et al., [4] investigated the effects of firing time and temperature on compressive strength, water absorption, bending strength, weight loss, firing shrinkage and densities of clay bricks. Their findings show that increasing firing time only slightly altered the mechanical and physical properties of clay bricks and firing temperature significantly affects the physical properties. This present research, however, is aimed at determining the mechanical, thermo-physical and filtration properties of dried clay mixtures of different sand concentrations for water storage vessel.

2. MATERIALS AND METHODOLOGY

The major raw materials used in this work are clay and sand particles. Two different types of clay were collected from two different locations: one from Igbara-Odo in Ilawe Local Government Area and the other one collected from Isan-Ekiti in Oye Local Government Area both in Ekiti State, Nigeria. Both collected clay were moulded with equal sizes of match box. Upon drying, it was discovered that the clay from Isan-Ekiti was more suitable for the work because of its handling strength (i.e. compressive strength) than that of Igbara-Odo, hence the choice of Isan-Ekiti became the samples needed for the course of the experiment. The sand was collected from a flowing stream near Ekiti State University health centre in the main campus. Because the

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sand was collected from a flowing stream, little washing was needed.

Material Preparation

The sand used was washed in a large volume of water in a bowl to remove dusts. After washing, the sand was allowed to dry properly. When the sand was certified dry, the sand was collected for sieve. The sieve helped to remove coarse sand.

Sieve Analysis

The already dried sand was subjected to particle size distribution (i.e. separating the finest sand from the coarse sand), using basket-like sieve of very tiny holes.

Filter Fabrication

For homogenous dispersion, the dry sand and clay were mixed thoroughly in various proportions by mass and water was added as a fine spray and mixed until a workable plastic constituent was achieved. Various samples were then made from between 0% and 100% of sand by mass for the same grain size of clay. Specifically, the following compositions of clay mixture were prepared: 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100% sand (balance clay) by mass. The filters were made in the form of a truncated cone close at one end. The filters fabricated were of the size of cone cups: 87mm for slant height, 86mm for base height, 209mm for main height, 123mm for minor height, 45mm for radius, 30mm for bottom radius and thickness of 5mm all through. The filters were allowed to cure properly in the sun for about two days.

Total surface area of the fabricated cone

The total surface area of the fabricated cone of sample clay is evaluated as follows:

$$A_{TC1} = \pi R^2 + \pi RS \quad (1)$$

$$A_{TC1} = \pi R\,(R + S) \quad (2)$$

$$S = \sqrt{(R^2 + H^2)} \quad (3)$$

$$A_{TC2} = \pi r^2 + \pi rs \quad (4)$$

$$A_{TC2} = \pi r\,(r + s) \quad (5)$$

$$S = \sqrt{(r^2 + h^2)} \quad (6)$$

$$A_{TC} = A_{TC1} – A_{TC2} \quad (7)$$

First, considering the larger cone:

R = 45mm = 0.045m; H = 209mm = 0.209m

From equation (3), we have:

$$S = \sqrt{(0.045^2 + 0.209^2)}\ \text{m}$$

S = 0.2138m or 213.8mm

From equation (2), we have:

$$A_{TC1} = 3.142 \times 0.045\ (0.045 + 0.2138)\ \text{m}^2$$

$$A_{TC1} = 0.0366\text{m}^2$$

Secondly, considering the smaller cone:

r = 30mm = 0.03m; h = 123mm = 0.123m

From equation (6), we have:

$$s = \sqrt{(0.03^2 + 0.123^2)}\ \text{m}$$

s = 0.1266m or 126.6mm

From equation (5), we have:

$$A_{TC2} = 3.142 \times 0.03\ (0.03 + 0.1266)\ \text{m}^2$$

$$A_{TC2} = 0.0148\text{m}^2$$

From equation (7), we have:

$$A_{TC} = (0.0366 – 0.0148)\ \text{m}^2$$

$$A_{TC} = 0.0218\text{m}^2$$

Compressive strength

The following were used as the apparatus for compressive strength test: Tensometer, precision, light compression attachments, drum, pointer, and mercury indicator. The compression test specimen was obtained by mixing different percentage of sand compositions and the same compositions of clay by mass (50g of clay). Before the compressive strength test was carried out on the specimen, they were allowed to dry at room temperature. The respective compression test specimen was placed in between the light compression attachment fixed to the tensometer which was tighten with the aid of a saddle. The hand-wheel of the tensometer was rotated and it subsequently rotates the drum on which a plotting paper was wound. The rotation of the drum as a result of the hand-wheel caused the pointer on the tensometer to manually indicate the compressive force (i.e. the maximum compressive force reached before the specimen is crushed) on the plotting paper. The plotted paper of the compressive force is then removed from the drum and the manually traced line of the force is now finally traced with a pencil. The compression force is now recorded. The compressive force reached after crushing is defined as the compressive force divided by the area of the compressed circle of the experiment. This is known as the engineering stress and is defined by compressive strength.

$$\text{Compressive strength} = \frac{F_C}{A_S}\ \text{Nm}^{-2} \quad (8)$$

Where:

$$A_s = \pi \frac{D_S{}^2}{4}\ \text{m}^2 \quad (9)$$

Hence, equating (1) and (2) we have:

$$\text{Compressive strength} = \frac{4F_C}{\pi {D_S}^2}\ \text{Nm}^{-2} \qquad (10)$$

D_s = 2.5cm = 0.025m and π = 3.141592654

Equation (3) now becomes:

$$\text{Compressive strength} = 2037.2F_c\ \text{Nm}^{-2} \qquad (11)$$

Using equation (11), the compressive strength for sample 1 was evaluated as:

$$(\text{Compressive strength})_1 = 2037.2 \times 3575\ \text{Nm}^{-2}$$

$$(\text{Compressive strength})_1 = 7281059.063\ \text{Nm}^{-2} \text{ or } 7.28\text{MNm}^{-2}$$

This analysis was repeated for samples 2,3,4,5,6,7,8,9,10 and 11 respectively as shown in Table 2.

Thermal conductivity

The following were used as the apparatus for the thermal conductivity test: Lee's disk apparatus, thermometers, T_1 and T_2, kerosene stove, disk shaped samples, gloves, stopwatch, tripod stand, and water drum. The specimen meant for the thermal conductivity test was obtained by mixing different percentage of sand compositions and the same composition of clay by mass (200g of clay). Before the thermal conductivity test was carried out on the specimen, they were allowed to dry at room temperature. The water drum was filled with water and was heated directly through a kerosene stove. The sample was placed in between the upper disk and lower disk. The upper disk was fixed with the steam chest. The upper disk, lower disk and the sample in between them was lagged (i.e. tied together) to reduce heat loss. When a steady state was reached (i.e. when the temperature of the upper and lower disk is constant) T_1 and T_2 were recorded. For the steady cooling time, the lower disk was heated directly with the kerosene stove until the temperature was 5^0C above the previous (steady state) value of T_2. The temperature increase was recorded as θ_1. The disk was then removed from the heat source and the sample was placed on it. By using a stopwatch to determine the cooling time, the sample on it cools until the temperature is 5^0C below the previous (steady state) value of T_2. The temperature decrease was recorded as θ_2. The sample used to measure the thermal conductivity using the Lee's disk method is in form of a disk whose thickness, x, is small relative to its diameter, D_d. This aspect ratio removes the need to lag the edge of the disk to reduce heat loss. Since the cross-sectional area of the disk, $A = \frac{\pi D_d^2}{4}$, is large compared with the exposed areas of the edge, $a_e = \pi D_d x$. Using a thin sample also means that the system will reach thermal equilibrium more quickly. Ignoring heat losses from the edge of the disk, the steady state of heat transfer by conduction is given by:

$$Q = KA\left(\frac{T_1 - T_2}{x}\right) \qquad (12)$$

If the disk cools at a rate of dθ/dt then the rate of heat loss is given by:

$$Q = mc_p\frac{d\theta}{dt} \qquad (13)$$

$$Q = mc_p\left(\frac{\theta1-\theta2}{t-t0}\right) \qquad (14)$$

Where t_0 = 0 at initial condition.

Therefore:

$$Q = mc_p\left(\frac{\theta1-\theta2}{t}\right) \qquad (15)$$

Substitute A for $\frac{\pi D_d^2}{4}$ into equation (5), we have:

$$Q = K\pi D_d^2\left(\frac{T_1 - T_2}{4x}\right) \qquad (16)$$

Equating equation (8) and (9), we have:

$$K = \frac{mc_p(\theta1-\theta2)4x}{\pi D_d^2(T1-T2)t} \qquad (17)$$

m = 250g = 0.25kg; D_d = 11cm = 0.11m; x = 0.01m;

c_p = 380Jkg^{-1}k^{-1}; dθ = $\theta_1 - \theta_2$ = 10 (It is constant all through the course of the experiment).

Equation (10) now becomes:

$$K = \frac{1000}{(T1-T2)t}\ \text{Wm}^{-1}\text{k}^{-1} \qquad (18)$$

Using equation (18), the thermal conductivity for sample 1 was evaluated as:

$$K_1 = \frac{1000}{(370.5-345.5)x3012}\ \text{Wm}^{-1}\text{k}^{-1}$$

$$K_1 = 0.0133\ \text{Wm}^{-1}\text{k}^{-1}$$

This analysis was repeated for samples 2,3,4,5,6,7,8,9,10 and 11 respectively as shown in Table 4.

Water filtrating capacity

The following were the apparatus used for the water filtrating test: calibrated beaker of 600ml capacity, rack, stop watch, water, and the truncated cone shaped-like samples of the sand-clay mixtures. Water storage and filtration samples were obtained by mixing different percentage of sand compositions and the same compositions of clay by mass (250g of clay). Before the filtration test was experimented on the cone-like samples, they were allowed to dry at room temperature. Determination of water filtrating capacity was evaluated for the samples. The samples were arranged in the rack stand in the order of 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100% sand (balance clay) by mass. The analysis for the filtrating capacity of the samples were taken after this order with varying time in the order of 0, 5, 10, 15,…, 395minutes using a stopwatch. Specific volume of water (100ml of volume) was poured in each of the sample and stopwatch was used to determine the water that was retained in each of the sample after filtration. A calibrated beaker was placed under the samples to determine the volume of water filtered. The volume of water filtered will be given an idea of the water retained in each of the sample. The result of each sample experiment was recorded. Filtration rate is defined as the differences between an actual volume of water in the sample before filtration and volume of water filtrated after filtration divided by the time taken in filtering the water. Mathematically,

$$\text{Filtration rate, } Q = \frac{VA - VB}{t_F}\ \text{cm}^3\text{min}^{-1} \qquad (19)$$

Using equation (19), the filtration rate for sample 1 was evaluated as:

$$Q_1 = \frac{100-0}{395}\ \text{cm}^3\text{min}^{-1}$$

$Q_1 = 0.2532\ \text{cm}^3\text{min}^{-1}$

This analysis was repeated for samples 2,3,4,5,6,7,8,9,10 and 11 respectively as shown in Table 6.

Permeability

Permeability is a physical property of porous materials, which determines the flow of fluid (e.g. water) through the material by an applied pressure gradient. It may be described as the “fluid conductivity” of the porous material. Permeability is commonly symbolized as “K”. Permeability of the samples can be calculated using the Darcy’s equation as below:

$$Q = \frac{KA}{\mu}\frac{dp}{dx}\ \text{cm}^3\text{s}^{-1} \qquad (20)$$

The usual unit of measuring of permeability of the samples is the Darcy. The Darcy unit represents the flow capacity required for 1ml of fluid to flow through 1 cm^2 for a thickness of 1cm when 1 atmosphere of pressure is applied.

$$dp = \rho g dH \qquad (21)$$

$$\rho = 100kgm^{-3}; g = 9.81ms^{-2}; dH = 0.052m; dx = 0.5cm;$$

$$\mu = 8.90\ x\ 10^{-4} pa.s$$
$$= 0.890\ centipoise\ of\ about\ 25^0C\ (i.e. room\ tempearture);$$

$A = A_{TC} = 0.0218\text{m}^2$

Evaluating for sample 1:

Using equation (21), we have:

$dp = 1000 \times 9.81 \times 0.052\ \text{Nm}^{-2}$

$dp = 510.12\text{Nm}^{-2} = 0.00503$ atm (since 1 atm = 10125pa)

Using equation (20), we have:

$$Q = 2.4641K \qquad (22)$$

Using equation (22), the permeability for sample 1 was evaluated as:

$$K_1 = \frac{Q_1}{2.4641} = \frac{0.00422}{2.4641} = 0.0017\ darcy$$

This analysis was repeated for samples 2,3,4,5,6,7,8,9,10 and 11 respectively as shown in Table 7.

3. RESULTS AND DISCUSSION

I. Compressive Strength

Table 1 and Figure 1 give different analysis for the compressive force of clay-sand mixture which indicates that the compressive force decreases with increase in percentage of sand. This result shows that sample without sand (0% sand) requires much force to be applied before compression can take place on the sample when compared with sample with lesser or more percentage of sand.

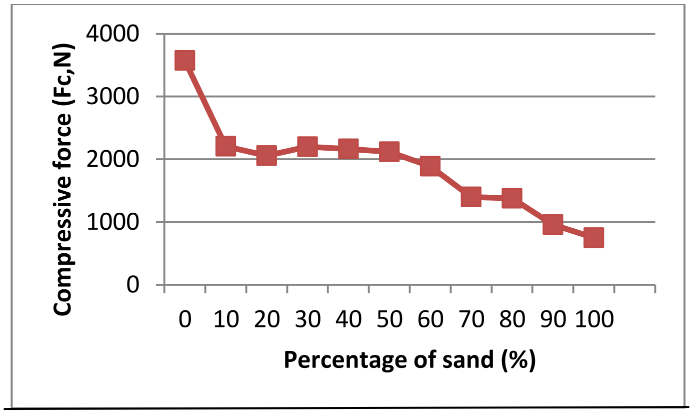

Figure 1: Graphical representation of compressive force against percentage of sand

Table 1: Compressive Force of the Samples

Sample	Percentage of sand (%)	F_c (N)
1	0	3575
2	10	2208
3	20	2058
4	30	2200
5	40	2166
6	50	2120
7	60	1890
8	70	1400
9	80	1379
10	90	960
11	100	750

Table 2 and Figure 2 which also gives different analysis for the crushing strength of clay-sand mixture indicate that the crushing strength decreases with increase in percentage of sand. This result shows that sample without sand (0% sand) is having very good handling strength compared with sample with lesser or more percentage of sand. This development or observation could be attributed to the fact that the adhesive forces of clay particles are reduced by sand inclusions. Also, sand inclusion in the clay matrix creates pores which acts as areas of stress concentration for easy fracture of the specimen.

Table 2: Crushing Strength of the Samples

Sample	Percentage of sand (%)	Crushing strength (MN/m^2)
1	0	7.28
2	10	4.50
3	20	4.19
4	30	4.48
5	40	4.41
6	50	4.32
7	60	3.85
8	70	2.85
9	80	2.80
10	90	1.96
11	100	1.53

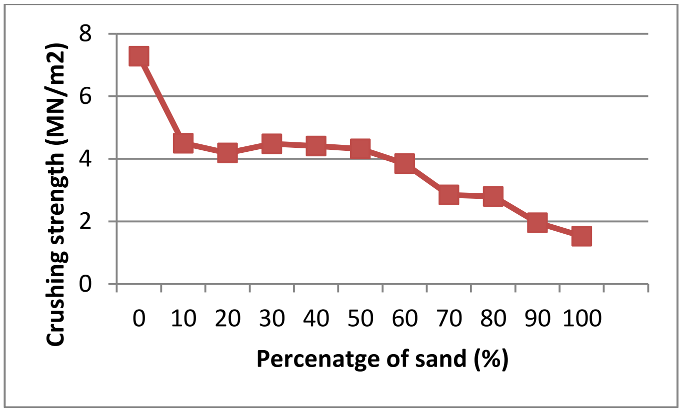

Figure 2: Graphical representation of crushing strength against percentage of sand

II. Thermal Conductivity

Table 3, Table 4 and Figure 3 which shows different analysis for the thermal conductivity of clay-sand mixture indicates that the thermal conductivity increases with increase in percentage of sand. This observation could be attributed to the grain size of sand that are not well interlocked in the clay mixture.

Table 3: Observation of change of Temperature against Time

	Steady temperature (k)				
Sample	Percentage of sand (%)	T1	T2	ΔT (k)	Time t(s)
1	0	370.5	345.5	25	3012
2	10	370.5	340.5	29.7	2300
3	20	370.5	340	30	2216
4	30	370.5	337.2	33.3	1290
5	40	370.5	335.2	35.3	1002
6	50	370.5	334	36.5	710
7	60	370.5	332.3	38.2	590
8	70	370.5	328	42.5	432
9	80	370.5	325	45.5	208
10	90	370.5	322	48.5	189
11	100	370.5	319.5	51.0	164

Table 4: Thermal Conductivity of the Samples

Sample	Percentage of sand (%)	Thermal conductivity K ($Wm^{-1}k^{-1}$)
1	0	0.0133
2	10	0.0146
3	20	0.0150
4	30	0.0233
5	40	0.0253
6	50	0.0386
7	60	0.0444
8	70	0.0545
9	80	0.1057
10	90	0.1091
11	100	0.1191

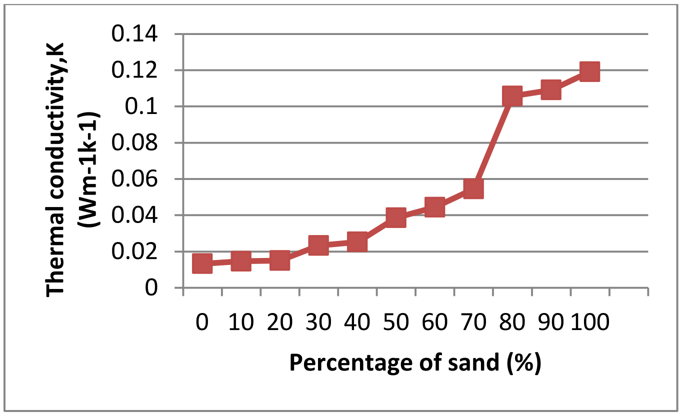

Figure 3: Graphical representation of thermal conductivity against percentage of sand

III. Filtration Rate Analysis

Table 5 shows different analysis for the volume of water retained after time, t indicates that the discharge of water increases as sand content increases. This observation could be attributed to the increase in permeability of the mixture. Table 6 and Figure 4 shows different analysis for the filtration rate of clay-sand mixture which indicates that filtration rate increases with increase in percentage of sand. This observation could be attributed to the percentage volume of void in the given samples.

Table 6: Filtration Rate of the Samples

Sample	Percentage of sand (%)	Q (cm^3/min)	Q (cm^3/s)
1	0	0.2532	0.00422
2	10	0.4167	0.006945
3	20	0.4255	0.00709
4	30	0.4545	0.007575
5	40	0.5000	0.00833
6	50	0.5263	0.00877
7	60	0.5714	0.00952
8	70	0.6452	0.01075
9	80	0.6897	0.011495
10	90	0.8000	0.01333
11	100	0.8696	0.01449

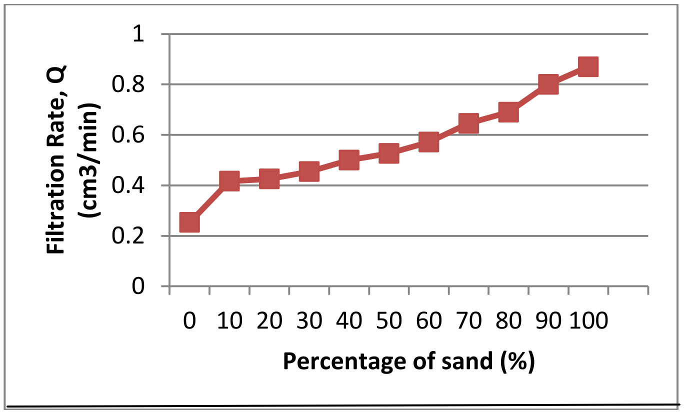

Figure 4: Graphical representation of filtration rate against percentage of sand

IV. Permeability

Table 7 and figure 5 shows different analysis for the permeability of clay-sand mixture which indicates that permeability increases as percentage of sand increases. This observation could be attributed to the higher percentage of void in the mixture.

Table 7: Permeability of the Samples

Sample	Percentage of sand (%)	K (Darcy)
1	0	0.0017
2	10	0.0028
3	20	0.0029
4	30	0.0031
5	40	0.0034
6	50	0.0036
7	60	0.0039
8	70	0.0044
9	80	0.0047
10	90	0.0054
11	100	0.0059

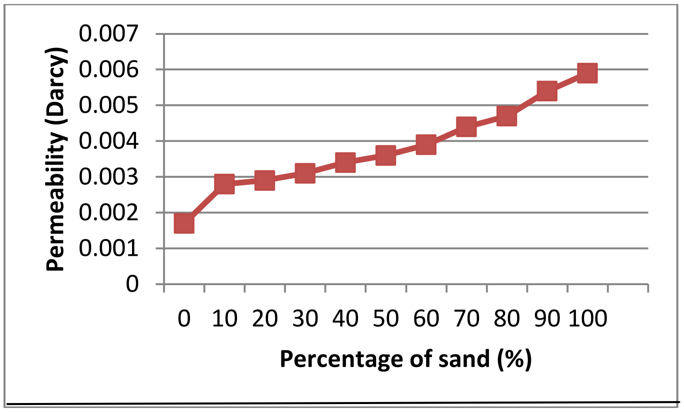

Figure 4: Graphical representation of Permeability against percentage of sand

Table 5: Experimental results of volume of water retained after time, t of the samples

Time(min)/Sample	Volume of water retained (ml)										
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
0	100	100	100	100	100	100	100	100	100	100	100
5	100	100	100	100	100	100	100	100	100	100	100
10	100	100	100	100	100	100	100	100	100	100	100
15	100	100	100	100	100	100	100	100	100	100	100
20	100	100	100	100	100	100	100	100	100	100	100
25	100	100	100	100	100	100	100	100	100	100	100
30	100	100	100	100	100	100	100	100	100	100	100
35	100	100	100	100	100	100	100	100	100	100	100
40	100	100	100	100	100	100	100	100	100	100	100
45	100	100	100	100	100	100	100	100	100	100	100
50	100	100	100	100	100	100	100	100	100	100	100
55	100	100	100	100	100	100	100	100	100	100	100
60	100	100	100	100	100	100	100	100	100	100	100
65	100	100	100	100	100	100	100	100	100	82	80
70	100	100	100	100	100	100	92	85	80	78	74
75	100	100	100	100	100	96	88	79	74	72	68
80	100	100	100	98	90	88	80	72	70	65	62
85	100	100	100	95	86	84	76	62	66	50	47
90	100	100	100	90	82	80	72	58	64	48	41
95	100	98	94	86	78	75	68	53	60	42	35
100	100	96	92	80	74	72	66	46	58	42	25
105	100	95	88	78	72	72	62	46	52	36	15
110	100	92	86	74	70	69	54	40	50	29	8
115	100	88	84	69	68	65	48	35	48	18	0
120	100	85	82	65	64	60	40	32	40	9	
125	100	80	78	62	62	56	36	28	32	0	
130	100	76	75	58	58	50	32	25	28		
135	100	74	72	55	52	45	28	21	20		

140	100	66	64	50	48	38	26	17	15		
145	100	62	60	48	42	30	20	10	0		
150	100	58	58	46	38	25	18	4			
155	100	55	50	40	32	22	15	0			
160	100	50	45	37	28	17	12				
165	95	46	40	34	22	12	7				
170	92	42	38	30	18	10	2				
175	90	38	36	30	16	10	0				
180	90	35	32	25	14	8					
185	88	34	30	22	14	6					
190	86	30	25	20	14	0					
195	86	26	22	16	6						
200	80	24	20	14	0						
205	78	22	18	10							
210	76	18	14	4							
215	75	16	12	4							
220	72	12	8	0							
225	70	12	6								
230	70	10	4								
235	68	6	0								
240	66	0									
245	64										
250	64										
255	64										
260	62										
265	60										
270	58										
275	56										
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320	38										
325	36										
330	32										
335	32										
340	28										
345	24										
350	22										
355	20										
360	19										
365	15										
370	12										
375	10										
380	8										
385	7										
390	2										
395	0										

CONCLUSION

The filtration and storage medium described in this paper study is a cheap and safe means of filtering and storing water for drinking purpose. The common domestic filter uses what is commonly called “filter cartridge” as its filtration medium and it is very expensive and not easily affordable to common man. However, the filtration and storage medium described here can be very useful and cheap to the common man if it is constructed in the form of a pot. This is because all raw materials needed for its fabrication are locally available. It can be concluded that because of the highest crushing strength, least thermal conductivity, least filtration rate and least permeability of clay-sand mixture with 0% sand will best serve storage purpose when fired (i.e. not fired). Also, for high quality filtration, clay-sand mixture with 10% weight of sand will serve filtration purpose because it filtered water is the cleanest when assessed visually.

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NOMECLATURE

A_{TC} = Surface area of the truncated cone, m^2
A_{TC1} = Surface area of the larger truncated cone, m^2
A_{TC2} = Surface area of the small truncated cone, m^2
Π = 3.142
g = Acceleration due to gravity = 9.81ms^{-2}
R = Base radius of the larger cone, m
S = Slant height of the larger cone, m
H =Height from the centre base radius of the larger cone, m
r = base radius of the smaller cone, m
s = slant height of the smaller cone, m
h = height from the centre base radius of the small cone, m
F_c = Compressive force, N
A_s = Area of compressive circle, m^2
D_s = Diameter of compressive circle, m^2
Q = Filtration rate, cm^3s^{-1}
K = Thermal conductivity of the sample, $Wm^{-1}k^{-1}$
T_1 and T_2 = Steady state temperature
x = Thickness of the sample, m
m = mass of the brass plate, g
D_d = Diameter of the sample, m
A = Cross-sectional area, m^2
Ƙ = permeability, Darcy
V_A = Actual volume of water poured into the sample, cm^3
V_F = Final volume of water after filtration, cm^3
t_f = Time taken after filtration, min
$\frac{dp}{dx} =$ Pressure gradient, $atmcm^{-1}$
$\frac{d\theta}{dt}$= Slope of the cooling rate of brass, ks^{-1}
$\mu =$ Viscosity of water = 8.90 x 10^{-4}pa.s = 0.890 centipoises
$\rho =$ Density of water =100 kgm^{-3}
dH = Infinitesimal depth, m