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Thermal Conductivity for Foamed Paste made of Cement and Cement kiln dust

Rafik K. Abdel Wahab^{1,2}

1 - A.Prof.Civil Engineering Department, Faculty of Engineering,Qena Branch- Al-Azhar University -
Egypt

2- Vice Dean of High Institute for Engineering and Technology In Obour City –Qalyobia -Egypt
Dr.rkhairy@gmail.com

Abstract

As with most large manufacturing industries, by-product materials are generated. Cement kiln dust is a by - product material of cement manufacturing process. The aim of this paper is to investigate the properties of foamed paste made of CKD in addition of different percentages of cement. Compressive strength and thermal conductivity were determined. Sixty three cubes in three groups with different densities, amount of cement, CKD, water and foaming agent were cast. The results were encourage to use the Foamed(Cement kiln dust – cement) Paste (FCKDC) as an insulation materials. The results indicates' a comparable value for thermal conductivity which vary from (**0.074- 0.3**) W/mk.

Keywords :Cement ; Cement kiln dust (CKD) ;Thermal conductivity ; Compressive strength ; Foamed Paste

1- Introduction

Cement manufacturing is a critically important industry in Egypt and throughout the world. In2006, U.S. cement plants produced 99.8 million metric tons of cement^[20] Worldwide production accounted for about 2.5 billion metric tons. As with most large manufacturing industries, by-product materials are generated. Cement kiln dust (CKD) is a significant by-product material of the cement manufacturing process. Cement kiln dust production is estimated at 15-20% of cement production , estimated at 420-560 million tons annually throughout the world^[15] .

This industrial waste is characterized by high softness (20 - 100 microns) and high proportions of chlorides, sulfates, alkalis and lime is a source of high risk in terms of health and environmental aspects. These industrial by-product and waste materials must be managed responsibly to ensure a clean and safe environment. Over the past several years dramatic advances have been achieved in the management and use of cement kiln dust, thus reducing its dependency on landfill disposal.^[5]

It was found that due to its high alkaline content , large quantities of CKD could not be returned to the kiln ^[21] ,but the higher alkalinity and finer particles in addition to their (sometimes)



cementitious properties, make these materials usable for several applications such as waste solidification^[13], replacement of Portland cement in concrete block manufacturing and ready mix concrete^[16] and use as agricultural soil amendments^[19]. The presence of free lime (CaO), the high alkali content and the high fineness of CKDs also make them potentially valuable materials for stabilizing soils^[6]. R.Siddique^[17] concluded that Cement Kiln Dust and wood ash could be successfully used as a partial replacement of cement in making controlled low-strength materials (CLSM). El – Sayed et al.[7] have investigated the effect of CKD on the compressive strength of cement paste and on the corrosion behavior of embedded reinforcement. The Study reported that up to 5% substitution of CKD by weight of cement had no adverse effect either on cement paste strength nor the reinforcement passivity. Batis et al^[4] Where it was found that when CKD and blast furnace slag are in proper ratio in ordinary Portland cement, the compressive strength and corrosion resistance of the mix increase. Salem et al^[18] have studied the hydration of cement pastes containing granulated slag and CKD made with and without silica fume. It was reported in their study that the hydraulic reactivities of granulated slag and silica fume as activated by raw CKD are relatively high as compared with those activated by washed CKD. Maslehuddin et al^[12] suggested to limit the amount of CKD in concrete to 5% since the chloride permeability and electrical resistivity data indicate that the chances of reinforcement corrosion would increase in case of 10% and 15% CKD. Wang et al^[11] mentioned that The test results show that replacing 5 percent of cement by weight with kiln dust produces a mix exhibiting slightly greater shrinkage and creep and greater setting time than plain concrete but does not adversely affect other properties of mortar or concrete.

One means of obtaining lightweight concrete is to introduce gas bubbles into the plastic mix of mortar (cement and sand) in order to produce a material with cellular structure^[3]. The strength of lightweight concrete may be reduced by high air contents. At normal air contents (4 to 6 percent), the reduction is small if slumps are 5 in. or less and cement contents are used as recommended^[1]. Foamed concrete is a versatile building material with a simple production method that is relatively inexpensive compared to autoclave aerated concrete^[10]

Foam concrete is created by uniform distribution of air bubbles throughout the mass of concrete. For very low densities 300-500 kg/m³ made with cement and foam only such densities is used in roof and floor as insulation against heat and sound, and is applied on rigid floors (because it is not a structural material). It is used interspaces filling between brickworks, insulation in hollow blocks and any other filling situation where high insulation properties are required.

As sustainability involves that the needs of present generation are met without wasting, pollution, harming or destroying the environment^[14].

It was found very useful to use waste material as CKD instead of cement to decrease the bad impact on the environment and converting these wastes into useful products for sustainability.

This study was conducted to recycle cement kiln dust with small amount of cement Not exceed 30% to produce a very good and cheap insulation materials.

2- Research significant

The importance of research lies in two things, the first is to take advantage of the cement kiln dust that pollutes the environment and the second is to obtain an economical material that is cheap and used for thermal insulation, which in turn leads to a reduction in the energy consumption needed to make buildings well air conditioned.

3- Materials

3-1 Cement

Ordinary Portland Cement From Qena Factory of cement had been used in this study and the chemical composites are shown in Table(1). The compressive strength test for cement had been done and the results was

(182 -274)kg/cm² for 3days and 7 days respectively.

3-2 Cement Kiln Dust (CKD).

CKD is a fine , highly alkaline powder from the same factory and Table(1) shows the chemical composites of CKD and cement used in this study.

Table(1)Chemical composites for Cement and CKD

Component	Portland cement (%)	Cement Kiln Dust (%)
SiO ₂	20.6	15.8
AL ₂ O ₃	4.5	3.6
Fe ₂ O ₃	3.6	2.8
CaO	62.5	63.8
MgO	2.6	1.9
SO ₃	2.7	1.7
K ₂ O	0.5	3.0
Na ₂ O	0.2	0.3
CL ⁻	0.01	1.1

3-3 Euco –Foaming- Agent

This is the name of the foaming material which is a product from Swiss-Kem company.

Euco-Foaming-Agent is a chloride free foaming agent to produce light weight concrete or mortar by entraining a controlled amount of air bubbles to the mix. It is high thermal and acoustic insulator. The dosage differ according to the density needed .The dosage used in this study is mentioned in Table (2).

4- Methods

4-1 Mix Proportioning

As mentioned in Table (2), three groups with different densities, amount of cement, CKD, water and foaming agent were tabulated. Number of cubes to be tested in compression test and thermal conductivity .

Table (2) Mix proportioning by weight

Group No.	Mix No.	Target Density (Kg /m ³)	Cement (Kg)	CKD (Kg)	Water (Lit.)	Foamed agent	No. of cubes for compressive strength	No. of cubes for thermal conductivity
G1	G11	500-550	6	24	24	10ml	6	1

	G12		9	21	22	10ml	6	1
	G13		12	18	20	10ml	6	1
G2	G21	600-650	6	24	24	8ml	6	1
	G22		9	21	22	8ml	6	1
	G23		12	18	20	8ml	6	1
G3	G31	700-750	6	24	24	6ml	6	1
	G32		9	21	22	6ml	6	1
	G33		12	18	20	6ml	6	1

4-2 Sample preparation

Sixty three cubes with size 100X100X100 mm had been cast with nine mix proportioning as mentioned in Table (2) . The cubes were divided to three main groups according to their density. Groups (G1),(G2)and (G3) represented mix with target density range from (500 -550),(600-650)and(700-750)kg/m³. A batch of 30kg of cement and CKD were prepared with different proportioning ratios .Mixes (G11),(G21)and (G31) had the same cement to CKD ratio which is 80% CKD and 20% cement and the foamed agent was 10 ml. Mixes (G12),(G22)and (G32) had the same cement to CKD ratio which is 70% CKD and 30% cement and the foamed agent was 8 mL. Mixes (G13),(G23)and (G31) had the same cement to CKD ratio which is 60% CKD and 40% cement and the foamed agent was 6ml.The produced paste was casted in the cubic mold without compaction and trawled .After 24 hours the specimens demolded and subjected to fresh air with average temperature of (25° C) ,average relative humidity 60% and subjected to curing twice a day by sprinkling water till the date of testing.

4-3 Test procedures

4-3-1 Compressive strength test.

Compression test was conducted by crushing six cubes, three after 7 days and the rest after 28 days All specimens had been tested under compression static load by using 2000kn compression testing machine with rate (0.6N/mm²) until failure .According to the Egyptian code C203^[8]

4-3-2 Thermal conductivity test

By using (KD2 Pro) picture (1) instrument nine specimens represented nine mixes had been tested to measure the thermal conductivity of each mix. The test was conducted after 28 days.

The test was conducted according to the standard specification ASTM C-518.The temperature was 24°C and R.H.55%.



Picture (1) KD2 Pro Instrument

5- Results and discussion

5-1 Results

Results had been tabulated in Table (3) as follows :

Table (3) shows the results of compressive strength tests after 7 &28 days and determination of thermal conductivity for all groups and different mixes .

Thermal resistance (**R**) had been calculated from the relationship^[9]

$$R= L/K \dots\dots\dots(1)$$

Where

R is thermal resistance

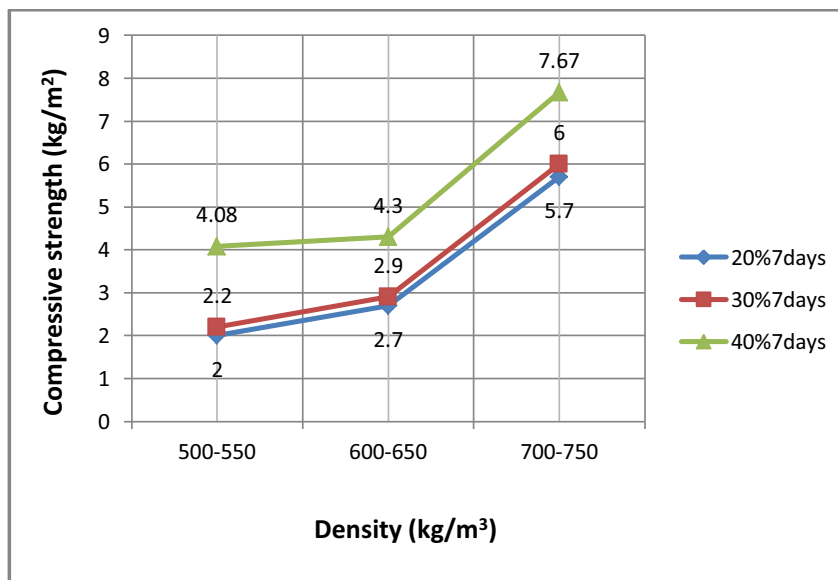
L is thickness of insulation material

K is the thermal conductivity of the insulation material

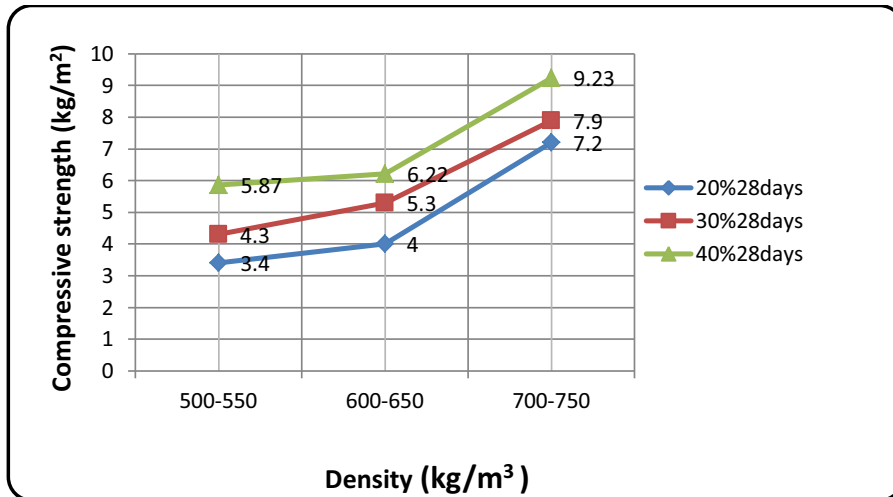
The equation (1) indicates that the lesser the thermal conductivity the higher thermal resistance . A relationship between density and compressive strength had been blotted in Figures (1) and (2).

Table(3) Compressive strength ,thermal conductivity Vs, Denisty and cement content

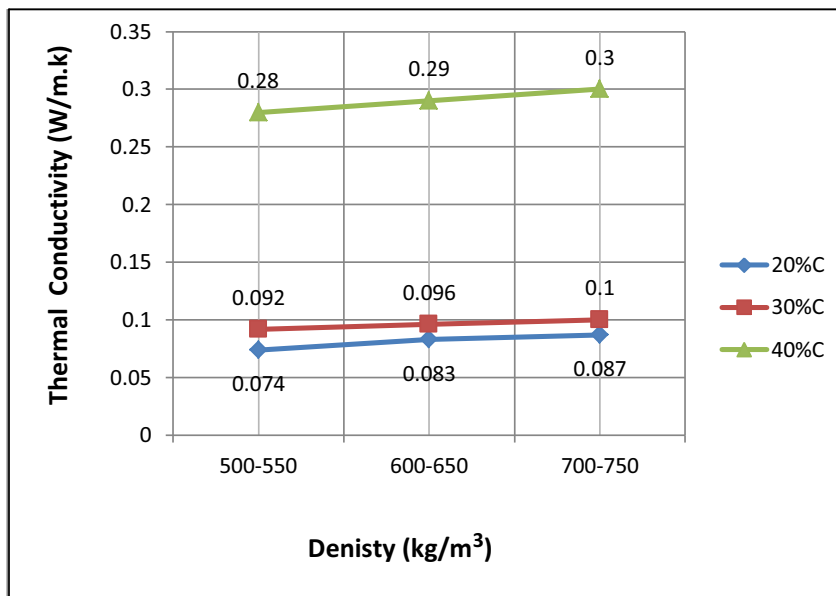
No. of Group	G1			G2			G3		
Density	500-550 kg/m ³			600-650 kg/m ³			700-750 kg/m ³		
Cement Percent by weight	20%	30%	40%	20%	30%	40%	20%	30%	40%
CKD substitution Percent by weight	80%	70%	60%	80%	70%	60%	80%	70%	60%
strength after 7 days (kg/cm ²)	2	2.2	4.08	2.7	2.9	4.3	5.7	5.99	7.67
Strength after 28 days (kg/cm ²)	3.4	4.3	5.87	4	5.3	6.22	7.2	7.89	9.23
Thermal Conductivity (W/m.K) after 28 days	.074	.092	.28	.083	.096	.29	.087	.1	.3
Heat insulation for 5 cm thickness(R)	68	54	18	60	52	17	57	50	17
Heat insulation for 10cm thickness (R)	135	109	36	120	104	34	115	100	33
Heat insulation for 15cm thickness(R)	203	163	54	180	156	52	172	150	50



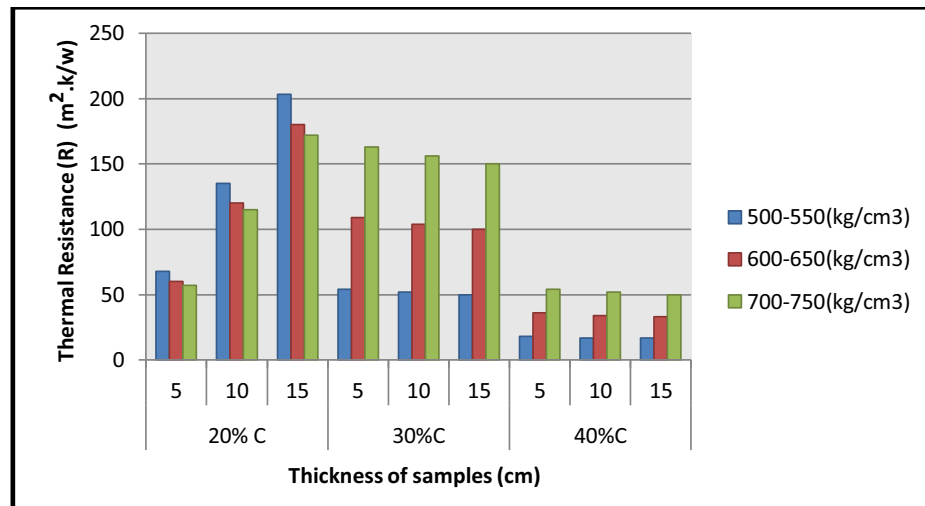
Fig(1) Compressive strength after 7 days Vs density and cement content



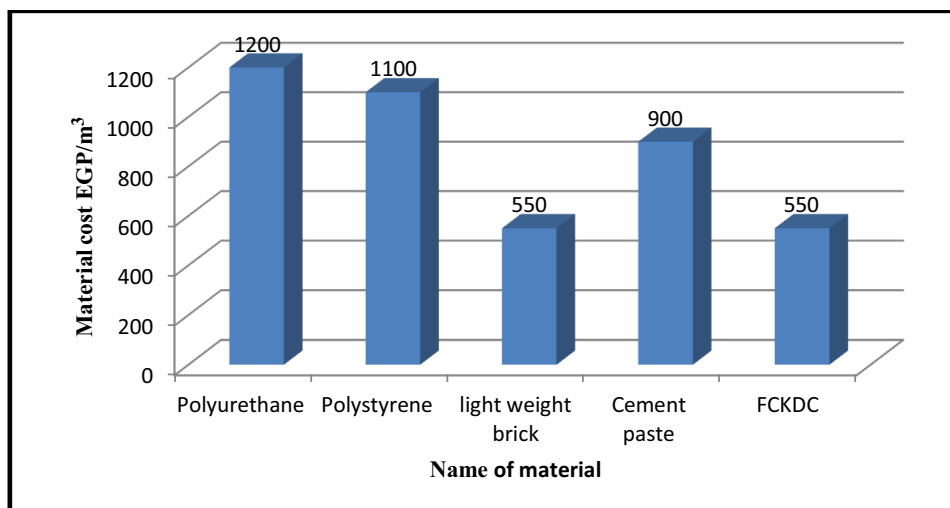
Fig(2) Compressive strength after 28 days vs Density and cement content



Fig(3) Thermal conductivity vs Density and cement content



Fig(4) Thermal resistance Vs Thickness ,densities and Cement content



Fig(5) Comparison of cost for different insulation materials Vs FCKDC

5-2 Discussions

The results as mentioned in Table (3) showed that the compressive strength for all specimen vary from 2 kg/cm² to 9 kg/cm² which is very low compared with the normal compressive strength for cement paste . But this compressive strength is accepted for the foamed paste from CKD and cement when it is compared with the strength of other insulation materials such as Expanded polystyrene which has compressive strength 1.73kg/cm², polyurethane (1-2 kg/cm²) and foamed concrete which has in very low density a compressive strength about 5 kg/cm² as mentioned in the Egyptian specifications for thermal insulation works^[9] . Also, the minimum compression strength

which is 2 kg/cm^2 is enough to carry a person weigh more than 100 kg as this material is not structural material but it is required for insulation only and not to be crushed under the foot of workers during application on ceiling. When applied this material in sandwich brick walls the property of compression strength is not important at all. As per Fig (1) and Fig(2) it is obviously observed that the compressive strength for (FCKDC) paste directly proportional with density. As regardless of the type of foamed paste or mortar, the strength increased when density increased. The results recorded a very good values of thermal conductivity which is varying from (0.074-0.3) W/mk. The low value for thermal conductivity (K) which means very high thermal resistance refer to the low density. The change of percentage of cement and CKD in mixes leads to change the thermal conductivity for the same density as observed from Fig.(3). for example at density equal to (500-550)kg/m³ the value of thermal conductivity for cement content(20% ,30%and 40%) were (0.074,0.92and 0.28) respectively. This change was probably related to the increase of CKD fineness than cement since the larger interface area would act as a thermal barrier decreasing the amount of heat transfer^[20]

6- Cost analysis for FCKDC paste

The cost of cubic meter of FCKDC is 550EGP, compared this value with pure cement paste which cost approximately 900EGP according to Fig(5) it could be safely save about 60%

7- Conclusion

- Foamed paste of Cement and CKD had a reasonable value in compressive strength as an insulation material.
- Foamed paste of cement and CKD had an excellent thermal resistance.
- Increasing the amount of CKD in Cement CKD paste leads to increase thermal resistance.
- The optimum value of cement percentage in Cement CKD paste from author point of view is 30% this is because the low thermal conductivity and the reasonable compressive strength.

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