Use of the Falling-head Method to Assess Permeability of Fly Ash Based Roof Tiles with Waste Polythene Fibre

M. N. Akhtar1, M. A. Khan2, J.N Akhtar3
1Lecturer Dept. of Civil Engineering Fahad Bin Sultan University, P.O. Box 15700, Tabuk, K.S.A (corresponding author). E-mail: nakhtar@fbsu.edu.sa , Mobile No +91966553846931
2Associate Professor Dept. of Civil Engineering, Aligarh Muslim University, Aligarh, P.O. Box 202002, India E-mail:mehboobcivil@yahoo.co.in
3Assistant Professor Univ., Polytechnic Civil Engineering section, A.M.U Aligarh, P.O. Box 202002, India, e-mail:jannisar_akhtar@rediffmail.com

Abstract- The falling-head method determined by using a permeameter cell is commonly used to study permeability (k) of soils and facility of fluids to travel through a solid skeleton. In present study, freshly mixed Flyash (F.A) based cementitious materials were studied. The Flyash of C category was used with different materials as a replacement of clay for making Flyash based roof tiles. Treated Flyash stone dust roof tiles (TFASDRT) were studied at varying percentages of Cement (C), Coarse sand (C.S) and Stone dust (S.D), with constant percentage of Waste Polythene Fibre (W.P.F). A research program was undertaken to evaluate the suitability of such test for assessing permeability of Flyash based freshly mixed mortars. The first combination of materials are at 70%, 60% & 50% of Treated Flyash (T.F.A) with the variation of Coarse Sand and Stone dust at 10% Cement and 1% Waste Polythene Fibre, the second combination at 50% T.F.A with the variation of Coarse Sand and Stone Dust at 15% Cement and the third and final combinations with 20% Cement were studied. It has been observed that the permeability of mortars was decreasing while increasing the cement content. Mixtures exhibiting lower levels of permeability were found to develop better statics stability including lower aggregate segregation and bleeding, together with improved hardened properties such as bonding to embedded reinforcement and develop compressive strength which is essential to make fly ash based roof tiles for the same proportion.

Keywords: Permeability; Flyash; Cement; Coarse sand; Stone dust; Waste Polythene Fibre.

1 Introduction

F.A particles typically solidify while they are still in suspension in exhaust gases and thus are generally spherical in shape. F.A is composed primarily of silica (SiO_2), alumina (Al_2O_3), and iron oxide (Fe_2O_3). Physical and chemical requirements for F.A usually vary depending on its intended use. Accordingly, specific requirements for use of F.A in concrete or soil stabilization are described in [1].(Standard Specification for Coal F.A and Raw or Calcined Natural Pozzolan for Use in Concrete) and ASTM C593-06 [2] (Standard Specification for F.A and Other Pozzolans for Use with Lime for Soil Stabilization), respectively. The plasticity index of mixture of fly ash and clay decrease dramatically with increasing of replacing ratio of F.A was to be determined according to [3]. Against the destructive action of rain, the incorporation of F.A in pozzolanic plaster provides a satisfactory resistance to aggressive chemicals such as sulfate, salts and acids by [4]. Hydraulic conductivity or simply permeability (k) of freshly mixed cementitious-based materials is a key indicator of hydromechanical properties (i.e., static stability, pumping, formwork pressure, plastic shrinkage) and their evolution with time. Several researchers reported that permeability of fresh concrete can be used to reflect its ability to remain homogeneous during the pumping and forming processes [5]. In the present study, F.A was used as a raw material to fully replace clay for making Fly ash roof Tiles. The aim of the present investigation is to find out a combination of materials, which gives minimum permeability and maximum compressive strength with F.A as a main constituent and cement, coarse sand, stone dust, lime, and waste polythene fibre as a subsidiary constituent. The quantity of cement was kept upto 20% for economic consideration. The waste polythene bags cutting pieces has been tried as admixture to the F.A for improvement in its performance against seepage characteristics compressive strength, fracture. Polythene is by nature a very slowly degrading compound. If it is stuck in the soil after being discarded, it does not allow water to seep in, as it is waterproof.

2 Experimental Program

2.1 Materials

The F.A conforming to [6] used in the study was the portion of the ash collected through electrostatics precipitators of Dadri Thermal Power Station, Dadri (U.P), India. The ordinary Portland cement of 43 Grade as per [7] was used. The types of waste polythene bags fibre were used in the experiment to carry daily usable items from general stores and shopping malls. The physical properties of different materials used in the study are given in Table 1.The finely ground calcium hydroxide, a laboratory regent, was used to augment the cementitious properties of the F.A. Its optimum amount with respect to optimum moisture contents (OMC) and maximum dry density (MDD) was determined through Standard Proctor's Test [8].Several tests were carried out in order to evaluate the seepage characteristics of Treated Fly ash based roof tiles.

Table 1. Material and their Physical Properties

Materials	Physical Properties	Value	Source
C (OPC) 43 Grade	Normal Consistency	28%	locally available
	Initial Setting Time	33 min	
	Final Setting Time	389 min	
	Compressive Strength	19.3MPa (3days)	
	(1:3 cement sand mortar)	28.5MPa (7days)	
	Tensile Strength	1.9Mpa (3days)	
	(1:3 cement sand mortar)	2.45Mpa (7days)	
T.F.A	Specific Gravity	1.92 (25^0 C)	Dadri Thermal Power Station (India)
	Optimum Moisture Content	18.2% (SPT)	
	Maximum Dry Density	1.28 gm/cc	
	Angle of shear resistance	29^0	
C. D	Specific Gravity	2.66	locally available
	Water Absorption (30min)	0.36%	
	Fineness Modulus	2.8	
	Silt Content	2.4%	
S. D	Specific Gravity	2.67	locally available
	Water Absorption (30min)	0.38%	
	Fineness Modulus	2.72	
	Silt Content	2.0%	
W.P.F	Length	5 mm	locally available
	Width	25 mm	

2.2 Moulds Ratio Flyash Mixed with different Materials

Six different combination grades of moulds (C: T.F.A: C.S: S.D by volume was used in the study, viz., 1:7:0:2, 20TFASDRT (70%TFA), 1:6:1:2, 20TFASDRT (60%TFA) and 1:5:2:2, 20TFASDRT (50%TFA) observed at lowest k ratios for the first phase of the observation. For phase second 1:5:1:3 30TFASDRT (10%C), 1:3.3:0.33:2 30TFASDRT (15%C) and 1:2.5:0:1.5 30TFASDRT (20% C) achieved lowest value of k.The value of k for six grades of moulds obtained by averaging the data from three observations of each grade.

2.3 Batching of Mixtures

The mixing procedure for the mortars consisted of homogenizing materials together with measured quantity of water mixing, and then introducing the cementitious materials gradually over 30 s. After a rest period of 30 s, the composite material was remixed for 2 additional min. As summarized in Table 3, six composite series made three with the variation of T.F.A and C.S, rest of the three in C with C.S at constant percentage of T.F.A. Three moulds of each combination were prepared for determine permeability level. The weighted material was placed on a level platform, W.P.F sprinkled gently on it and was mixed using mixer. Care was taken to prevent agglomeration of fibres and to ensure their uniform distribution as far as possible. The fresh mortar was poured into three equal layers in the mould also properly placed and compacted. In each series, different combinations with T.F.A, C and C.S were tested at the same combination of S.D and W.P.F. Testing and sampling of all composite mixtures were made at room temperature 25 ± 2˚C.

3 Permeability Testing of Mortars and Concrete

In general, permeability of soils is measured using a permeameter test following either the constant-head or falling-head method. The former method is recommended for coarse-grained soils where k is expected to be smaller than 10^{-5} cm/s, or when the soil contains 90% or more particles that are retained on the 75-µm sieve [9]. . Conversely, the falling-head test is suited for testing fine- grained soils where the k value is expected to be within the range of 10^{-5} to 10^{-8} cm/s, or when the soil contains 10% or more particles passing the 75-µm sieve. Therefore, the falling-head method was selected in this study for testing mortar and concrete materials containing fine particles such as cement and silica fume. A commercially available soil permeameter apparatus was used for testing. To avoid entrapment of air, the tested material was well compacted using a tamping device in three layers of approximately similar heights. Two filter papers were placed between the upper and lower perforated plates and the tested material to retain approximately 96% of all particles greater than 1 µm. De-aired distilled water

ISSN 2229-5518

at room temperature was used during testing. This is essential to minimize the amount of air dissolved in water, which can collect fine bubbles at the solid particles/water interface and reduce permeability [10]. More details on the falling-head method determined on soils can be seen in various geo- technical books such as [9]. The permeameter stand consisted of a metal frame with water tank adjustable in height between 1,500 and 4,500 mm. The value of hydraulic gradient (i) is being calculated as the ratio of total head of water under motion to the length of tested specimen. After opening the inlet water valve on top of the cell, outflow is observed to ensure a continuous flow regime (i.e., indicating complete saturation of the tested specimen) where water constantly trickles out from the out- flow valve (Fig. 1).

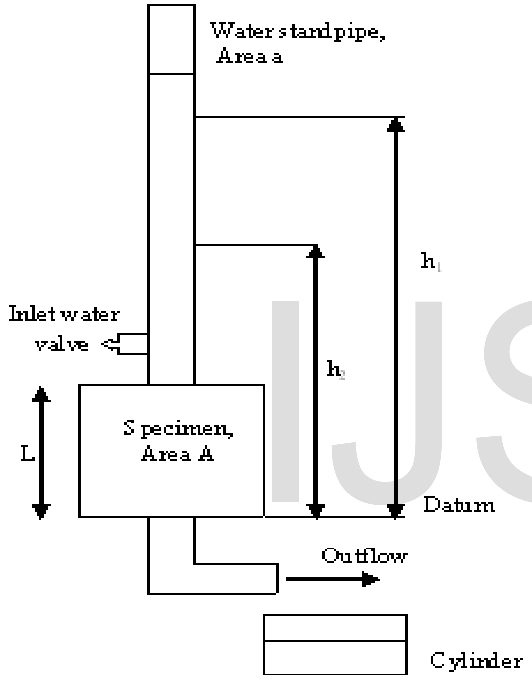


Fig. 1. Sketch for the permeameter test, falling-head method

The time needed to reach such regime varied from 4 to 10 min, depending on mixture composition. After ensuring continuous flow, the value of k was determined as follows:

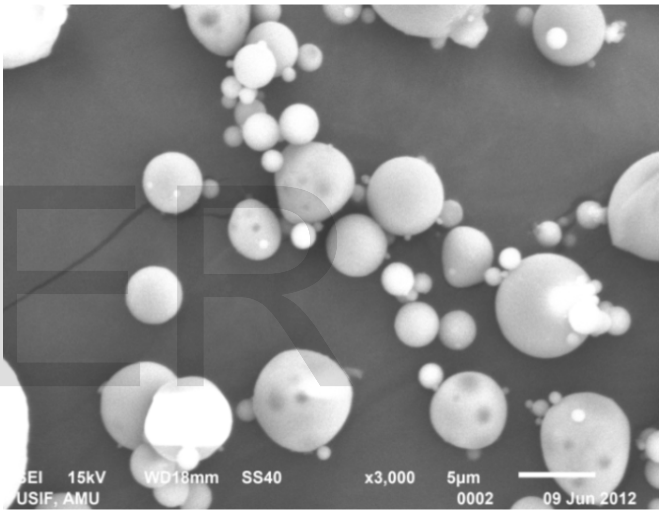
$$K\ (cm/s) = \frac{a}{A} \times \frac{L}{\Delta t} \times \ln\left(\frac{h1}{h2}\right)$$

where a (cm^2) = cross-sectional area of the inlet water valve (equal to 2.01 cm^2), A (cm^2) = cross-sectional area of specimen, L (cm) = height of specimen, and Δt (s) = time needed for the total head to drop from clearly marked graduations h_1 to h_2 (Fig.1).

3.1 Affecting Permeability of Composite Material

It has already been seen how the soil type can make such difference to the value of permeability. e.g., clean gravel has a k value greater than 10° cm/s, sand between 10° and 10^{-3} cm/s, silt between 10^{-3} and 10^{-6} cm/s and clay has k values smaller than 10^{-6} cm/s. The variation in the value of permeability is so large that we are interested mostly in determining the power to which 10 must be raised while expressing the permeability value [11]. In the present study we are interested to evaluate the permeability of composite material in which F.A as a main constituent and other materials are subsidiary. F.A consists of fine, powdery particles that are predominantly spherical in shape, either solid or hollow, and mostly glassy in nature. The particles size distribution of most bituminous coal Fly ashes is generally similar to that of silt (less than 0.075mm). Although, Sub-bituminous coal Fly ashes or class C Fly ash is generally slightly coarser than bituminous coal ranges between 0.002 mm - 0.1 mm. As can be seen in Fig. 2, the variation of particles in Scanning Electron Microscope (SEM): Flyash Particles at 3,000x Magnification and Fig. 3, shows Energy- dispersive X-ray spectroscopy (EDS) spectrum of plain Flyash.

Fig. 2. Scanning Electron Microscope (SEM): Flyash Particles at 3,000x Magnification



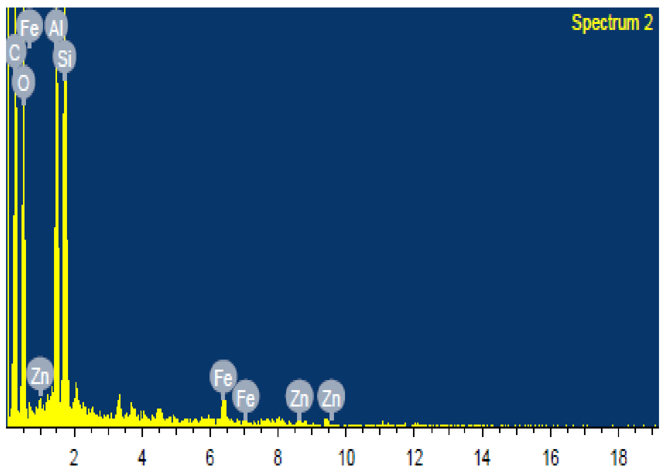
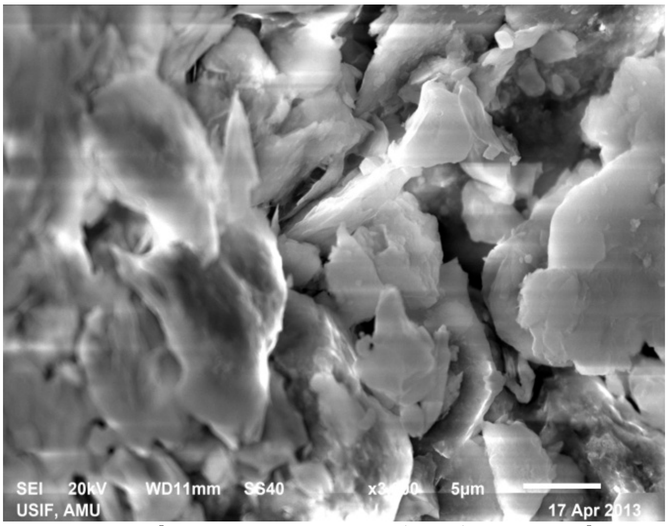


Fig. 3. Energy-dispersive X-ray spectroscopy (EDS) spectrum of plain Flyash

Construction materials such as Stone Dust (S.D) admixtures are mixed with cement particles and improve the particle packing of cement paste, thus reducing permeability (k). Fig. 4 and 5 shows the



Scanning Electron Microscope (SEM): Stone dust particles at 3000 x magnification and Energy-dispersive X-ray spectroscopy (EDS) spectrum of plain Stone dust.

Fig.4.Scanning Electron Microscope (SEM): Stone dust particles at 3000 x magnification

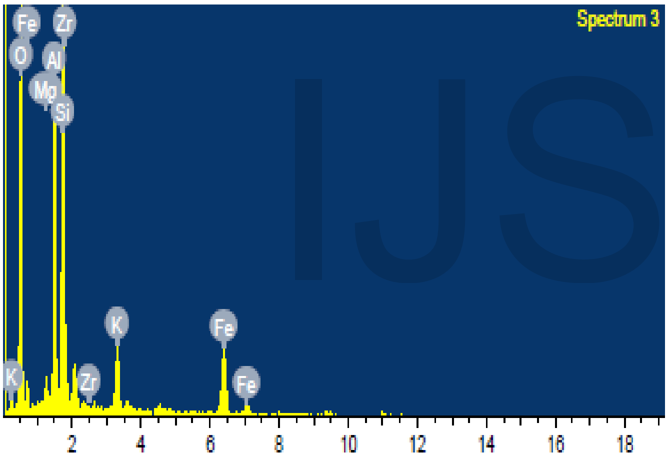


Fig.5. Energy-dispersive X-ray spectroscopy (EDS) spectrum of plain Stone dust

4 Result and Discussion

4.1 Discussion on permeability

Permeability (k) of individual composite material is summarized in Table 2. It shows the variation in mixed materials ranges from 10^{-4} to 10^{-8}. In fresh materials increases (k) depends on the particle size variation with their shapes.

Table 2. k values of mixed materials

Material	Permeability, k (m/s)
Fly ash (F.A)	1.650×10^{-5}
Stone dust (S.D)	3.610×10^{-6}
Coarse sand (C.S)	1.120×10^{-4}
Cement (C)	4.150×10^{-8}

As summarized in Table 3, six composite series made three with the variation of T.F.A and C.S and rest of the three in C and C.S. In Table 3, the permeability of different combinations with their ratios is given. As it can be seen in Table 3, phase 1 the permeability is minimum at 60% of T.F.A combination 20 TFASDRT. At 50% T.F.A combination with C.S (40 to 20) found increases in (k). So in this approach set maximum percentage of F.A as 50% in all combination of phase 2. A perusal of Table 3, phase 2 showed that the permeability of composite material is changed with the percentage of C and C.S. It has been observed that the changing in the variation of C with C.S effect on k, the value of k reduces with increases of C at varying percentage of C.S. It is observed that in Table 3, phase 2 the value of k reduces linearly with the increment of cement content. From the analysis of the obtained results of phase 2, follows that the composite materials samples with a high percentage of C lead to lower the value of k and hardening in comparison to the sample prepared only with 10% of C. The percent content of cement increases upto 20% with same percentage of W.P.F, and it has been observed that all sample at 20% C reached the minimum value of k and (30TFASDRT) achieved the lowest value of k. Fig. 6, illustrates the permeability k of samples at 70, 60 and 50% of T.F.A. As it can be seen in Fig. 6, from all the samples (00 TFASDRT to 20 TFASDRT) based on 10% C reached the lowest value of k at 60 T.F.A.

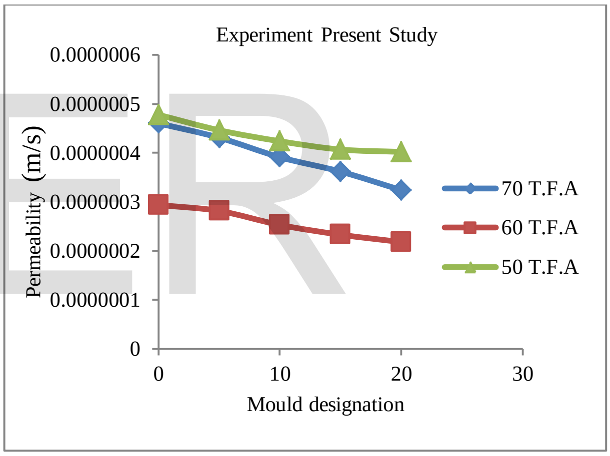


Fig.6. Variation of permeability with T.F.A and C.S.

Fig. 7 shows that k value of the entire sample (10 TFASDRT to 30 TFASDRT) from phase 2, the considerable decrease in k value reached the lowest at 20% C. It can also be seen that the variation in C.S also

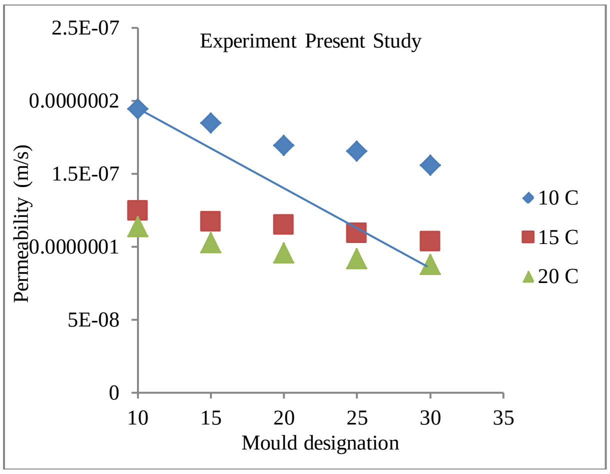


Fig.7. Variation of permeability with T.F.A and C.

Table 3. Typical Results of k with (70, 60 and 50% of T.F.A and 10, 15 and 20% of C)

Mould Designations	Mix Proportions C (%)	T.F.A (%)	C.S (%)	S.D (%)	W.P.F (%)	K_{27} (m/s)	Ratios of sample
Phase 1							
00 TFASDRT	10	70	20	00	1	4.603×10^{-7}	1:7:2:0
05 TFASDRT	10	70	15	05	1	4.310×10^{-7}	1:7:1.5:0.5
10 TFASDRT	10	70	10	10	1	3.911×10^{-7}	1:7:1:1
15 TFASDRT	10	70	05	15	1	3.618×10^{-7}	1:7:0.5:1.5
20 TFASDRT	10	70	00	20	1	3.240×10^{-7}	1:7:0:2
00 TFASDRT	10	60	30	00	1	2.937×10^{-7}	1:6:3:0
05 TFASDRT	10	60	25	05	1	2.815×10^{-7}	1:6:2.5:0.5
10 TFASDRT	10	60	20	10	1	2.529×10^{-7}	1:6:2:1
15 TFASDRT	10	60	15	15	1	2.330×10^{-7}	1:6:1.5:1.5
20 TFASDRT	10	60	10	20	1	2.180×10^{-7}	1:6:1:2
00 TFASDRT	10	50	40	00	1	4.777×10^{-7}	1:5:4:0
05 TFASDRT	10	50	35	05	1	4.462×10^{-7}	1:5:3.5:0.5
10 TFASDRT	10	50	30	10	1	4.238×10^{-7}	1:5:3:1
15 TFASDRT	10	50	25	15	1	4.068×10^{-7}	1:5:2.5:1.5
20 TFASDRT	10	50	20	20	1	4.020×10^{-7}	1:5:2:2
Phase 2							
10 TFASDRT	10	50	30	10	1	1.941×10^{-7}	1:5:3:1
15 TFASDRT	10	50	25	15	1	1.844×10^{-7}	1:5:2.5:1.5
20 TFASDRT	10	50	20	20	1	1.691×10^{-7}	1:5:2:2
25 TFASDRT	10	50	15	25	1	1.650×10^{-7}	1:5:1.5:2.5
30 TFASDRT	10	50	10	30	1	1.555×10^{-7}	1:5:1:3
10 TFASDRT	15	50	25	10	1	1.244×10^{-7}	1:3.33:1.66:0.66
15 TFASDRT	15	50	20	15	1	1.169×10^{-7}	1:3.33:1.33:1
20 TFASDRT	15	50	15	20	1	1.147×10^{-7}	1:3.33:1:1.33
25 TFASDRT	15	50	10	25	1	1.088×10^{-7}	1:3.33:0.66:1.66
30 TFASDRT	15	50	05	30	1	1.032×10^{-7}	1:3.33:0.33:2
10 TFASDRT	20	50	20	10	1	1.134×10^{-7}	1:2.5:1:0.5
15 TFASDRT	20	50	15	15	1	1.025×10^{-7}	1:2.5:0.75:0.75
20 TFASDRT	20	50	10	20	1	0.953×10^{-7}	1:2.5:0.5:1
25 TFASDRT	20	50	05	25	1	0.914×10^{-7}	1:2.5:0:25:1.25
30 TFASDRT	20	50	00	30	1	0.874×10^{-7}	1:2.5:0:1.5

plays a significant role to change the value of k. Fig. 8 and 9 shows the variation of k with T.F.A and C by equation graphs. The nature of the graphs with their related equations shows the linear variation in terms of y and x.

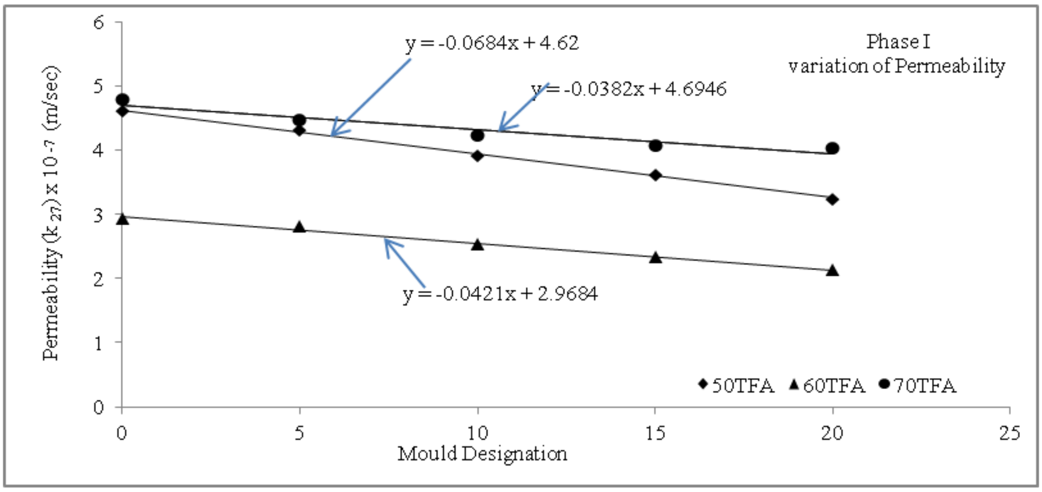


Fig.8. Variation of k with T.F.A by equation graph

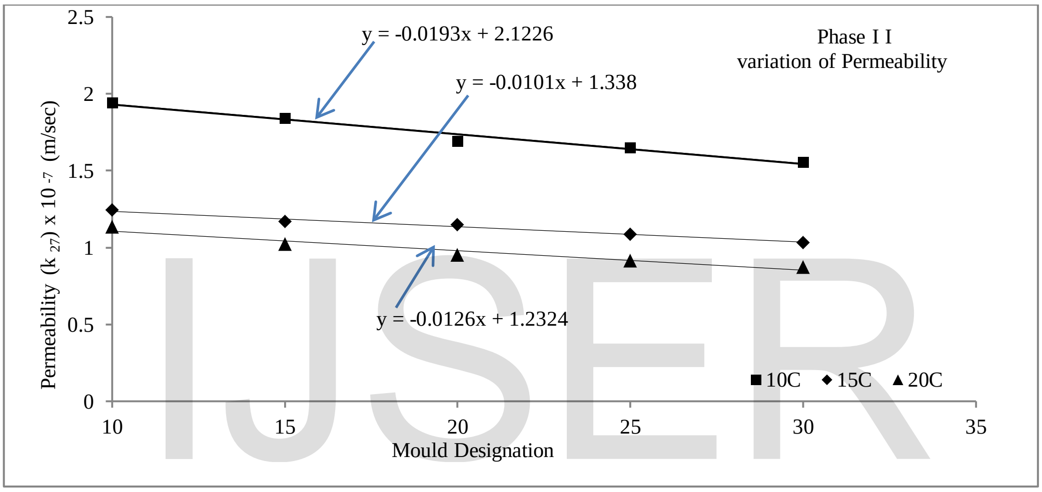


Fig.9. Variation of k with C by equation graph

4.2 Strength of mortar

The permeability of freshly mixed mortar was found nearly equal to the permeability of clay. The clay roof tiles are available in the market and they fulfilled the strength requirement which is about to 9 N/mm². The available prepared mortar in which the cement is using as a binding material F.A, W.P.F as a waste materials and coarse sand, stone dust as a natural natural materials. The prepared Flyash based roof tiles composite material will sustain same strength than clay roof tiles in the market. These tiles will be used on roof in the roof terracing work and they are not subjected to heavy loads structure over it, so the Flyash roof tiles fullfill all the basic requirements.

5 Conclusions

The objective of the research was to investigate experimentally the seepage behavior of freshly mixed Flyash based cementitious materials. The falling-head method realized using a soil permeameter is suitable to assess permeability of freshly mixed mortars. The experimental study reveals that the lower permeability values were obtained when increasing the percentage of C at fixed percentage of T.F.A and S.D. Whereby k dropped sharply with variation of C.S with C. The Fly ash mixed with W.P.F is supportive in enhancing the strength of mortar, furthermore their use, helps to reduce environmental pollution and save energy. In this study, we are using two important waste materials to make the Flyash based roof tiles cementitious materials. The safe utilization of these two waste materials is very essential for the protection of our environment. The use of Flyash will also reduce the land required for ash dump yards. By the utilization of Flyash for making roof tiles an equal volume of top soil, which will otherwise be used for making clay, tiles can be saved. Mixing of W.P.F enhances the effect on the strength of tiles and it does not allow water to seep in, as it is water proof. Consumption of W.P.F reduces the harmful, adverse effects of polythene that they block the drains and it is not mixed with the soil. Conclusion made in the present study may change based on different combination of cement, lime, sand, W.P.F and T.F.A used with other different waste materials.

ISSN 2229-5518

6 Lists of Symbols

The following symbols are used in this study.

FA: Flyash;
TFA: Treated Flyash;
TFASDRT: Treated Flyash Stone dust Roof tile;
C: Cement;
C.S Coarse Sand
S.D: Stone Dust;
W.P.F: Waste Polythene Fibre;
OMC: Optimum Moisture Contents;
K: Permeability;

6.1 Acknowledgements

The writers gratefully acknowledge the help of the staff at the soil mechanics laboratory at A.M.U Aligarh, India, in conducting the experiments.

7 References

[1] ASTM, (2005). "American Standards for Testing and Materials", Standard C618-05 "Standard specification for coal fly ash and raw or calcined natural pozzolan for use in concrete".
[2] ASTM, (2006). "American Standards for Testing and Materials". Standard C593-06 "Standard specification for fly ash and other pozzolans for use with lime for soil stabilization".
[3] Xu Lingling, Guo Wei, Wang Tao and Yang Nanru. (2005). "Study on fired bricks with replacing clay by fly ash in high volume ratio Construction and
[4] N. Degirmenci and B. Baradan (2005). "Chemical resistance of pozzolanic plaster for earthen walls Construction and Building Materials" 19: 536–542.
[5] Browne, R. D., and Bamforth, P. B. (1977). "Tests to establish concrete 15585 pumpability." ACI Struct. J., 74(5), 193–203.
[6] I.S: 3812 (1983) "Specification for Fly ash as pozollana and admixture" (First Revision).
[7] I.S: 8112 1989): 43 Grade ordinary Portland cement specifications (First Revision).
[8] I.S: 2720-8 (1983): Methods of test for soils, Determination of water content-dry density relation using heavy compaction.
[9] Das, B. M. (2010). Principles of geotechnical engineering. 7th Ed., 16592 Cengage Learning.
[10] Engineers Manual. (1986). "Determination of permeability of soil and 17594 chemical composition of water." EM 1110-2-1901.
[11] Gopal, Ranjan and A.S.R Rao. (2000). "Basic and Applied Soil Mechanics" New Age International (P) Limited, Publishers. 2nd Ed., ISBN (13): 978-81-224-1223-9
[12] ASTM, (2001a). "Standard test method for compressive strength of hydraulic cement mortars (using 2-in or 50-mm cube specimens)." Masonry test methods and specifications for the building industry, ASTM C 109/C 109M-99, 4th Ed., Philadelphia.
[13] ASTM, (2001b). "Standard test method for compressive strength of masonry prisms." Masonry test methods and specifications for the building industry, ASTMC 1314-00a, 4th Ed., Philadelphia.
[14] ASTM, (2001c). "Standard test methods for sampling and testing brick and structural clay tile." Masonry test methods and specifications for the building industry, ASTM-C67-00, 4th Ed., Philadelphia.
[15] Chidiac SE and Federico LM (2007). Effects of Waste Glass Additions on the Properties and Durability of Fired Clay Brick. Canadian J. Civil Eng., 34: 1458-1466.
[16] Cicek T, and Tanriverdi M (2007). Lime Based Steam Autoclaved Fly Ash Bricks. Constr. Build. Mater., 21: 1295-1300.
[17] Demir I et al. (2009). Reuse of Waste Glass in Building Brick Production.Waste Manage. Res., 27: 572-577.
[18] Demir I, et al. (2005). Utilization of Kraft Pulp Production Residues in Clay Brick Production. Build. Environ. 40:1533 1537.
[19] Dondi M, et al. (2009). Recycling of PC and TV Glass in Clay Bricks and Roof Tiles. Waste Manage., 29:1945-1951.
[20] Indian Standards (IS.1992a). Indian standard methods of test of burn clay building bricks—Part 1: Determination of compressive strength, IS 3495, 3rd Rev., Bureau of Indian Standards, New Delhi, India
[21] Kumar S (2002). A Perspective Study on Fly Ash–Lime–Gypsum Bricks and Hollow Blocks for Low Cost Housing Development. Construction and Building Materials. 16: 519-525.
[22] Kalwa M and Grylicki M (1983). Utilization of Fly Ash, a Waste from Thermal Power Stations, in Manufacture of Building Materials. Materials Science Monographs: pp. 107-109.
[23] Kavas T (2006). Use of Boron Waste as a Fluxing Agent in Production of Red Mud Brick. Building and Environment. 41: 1779-1783.
[24] Loryuenyong V et al. (2009). "Effects of Recycled Glass Substitution on the Physical and Mechanical Properties of Clay Bricks". Waste Management. 29: 2717-2721.
[25] Malhotra SK and Dave NG (1992). Development of Lime Slag Mixture. In:Proceedings of the National Conference on Cement and Building Materials from Industrial Wastes, Hyderabad, India, pp 94-101.
[26] Hemant B. Kaushik et al. 2007). Stress-strain Characteristics of Clay Brick Masonry under Uniaxial Compression. Journal of Materials in Civil Engineering, Vol. 19, No. 9, September 1,

2007.@ASCE, ISSN 0899-1561/2007/9-728-739. DOI: 10.1061/(ASCE)0899-1561(2007)19;9(728)

[27] Mun KJ, et al. (2007). Basic Properties of Non-Sintering Cement Using Phosphogypsum and Waste Lime as Activator. Construction and Building Materials, 21: 1342-1350.

[28] Murty, A.V.S.R.(1996). "Fly ash in Construction of Roads and Embankments", Central Road Research Institute India.

[29] Mroueh, U. M. and Wahlström, M., (2002). "By-products and recycled materials in earth construction in Finland—an assessment of applicability," Resources, Conservation and Recycling, No. 35, 2002, pp. 117–129.

[30] Nasly MA and Yassin AAM (2009) Sustainable Housing Using an Innovative Interlocking Block Building System. In: Proceedings of the Fifth National Conference on Civil Engineering (AWAM '09): Towards Sustainable Development, Kuala Lumpur, Malaysia, pp. 130-138.

[31] Pappu A, Saxena et al. (2007). Solid Wastes Generation in India and their Recycling Potential in Building Materials. Building and Environment, 42: 2311-2320.

[32] Park SB et al. (2004). Studies on Mechanical Properties of Concrete Containing Waste Glass Aggregate. Cement and Concrete Research, 34: 2181-2189.

[36] Rahman MA (1987). Properties of Clay-Sand-Rice Husk Ash Mixed Bricks. International Journal of Cement Composites and Light weight concrete, 9: 105-108.

[33] Rahman MA (1988). Effect of Rice Husk Ash on the Properties of Bricks Made from Fired Lateritic Soil-Clay Mix. Materials and Structures, 21:222-227. Building Materials" 19: 243–247.