ISSN (e): 2250 – 3005 || Volume, 06 || Issue, 09|| September – 2016 ||
International Journal of Computational Engineering Research (IJCER)

Effect of Sand to Fly Ash Ratio on the Hardened Properties of Geopolymer Mortar

Supratim Guha[1], Srijita Dey[2], Prakash Sarkar[3], Arindam Routh[3]
[1]Pursuing M.Tech, Energy and Environment Engineering, VIT University, Vellore, India
B.Tech Civil Engineering, Camellia School of Engineering & Technology, Kolkata, India
[2]Pursuing M.Tech, Geotechnical Engineering, Meghnad Saha Institute of Technology , Kolkata, India
B.Tech Civil Engineering, Camellia School of Engineering & Technology, Kolkata, India
[3] B.Tech, Civil Engineering, Camellia School of Engineering & Technology, Kolkata, India

ABSTRACT

This paper presents the progress of research on making Geopolymer mortar using the fly ash obtained from Kolaghat Thermal Power Station, (KTPS), Kolaghat, India. This paper results the report of the experimental study on mechanical property in terms of compressive strength that tested after heat curing in oven by varying fly ash to sand ratio 1:1 to 1:3. Sodium Hydroxide was used as alkali activator in this process. The two main parameters are .Synthesis parameter, i.e. alkali content, sand to fly ash ratio in geopolymer mixture, and Processing parameters i.e. mixing time, curing time, curing temperature to develop the compressive strength was studied. The test results show that, by increasing the sand to fly ash ratio compressive strength decreases. Again this feature was further backed up by typical properties like Water absorption, Sorptivity & Apparent Porosity

Keywords: *Alkaline solution, Compressive strength, Fly ash, Geopolymer mortar, Sorptivity, Water absorption*

I. INTRODUCTION

Cement is one of the most extensively used construction material, second only to water. In all over the world, day by day constructional works are increasing and to fulfill its requirement the production of Portland cement as a binder material is increases too and simultaneously the emission of carbon dioxide increases. By the production of Portland cement, the annual emission of greenhouse gas in 2005 is nearly about 8% of its total emission to the atmosphere [1]. The emission of CO_2, from the production Portland cement is mainly due to the calcinations of limestone and the combustion of fossil-fuel [1]. As per research one ton Portland cement produce same amount of carbon dioxide. [2].

To reduce this problem and to develop in construction work, geopolymer is introduced as a construction material. It is an inorganic, aluminosilicate binding material, developed by Joseph Davidovits in 1978[3,4]. Geopolymerization is a rapid reaction of aluminosilicate source material and alkaline activator solution and resulting in the formation of 3-D polymeric chain structure of Si-O-Al bonds [5]. The alkaline solution (combination of sodium hydroxide & sodium silicate or potassium hydroxide & potassium silicate) induce Al-Si atoms in source material (fly ash) to dissolve in the solution. Since it is a poly-condensation reaction, the gel formation is done by heating. The heating temperature of geopolymer mortar varies for different raw materials, and the molar concentration of the activator solution.

For making conventional mortar cube, cement and sand are the most important construction materials. Sand acts as a filler material in making of mortar and also increases crushing strength and reduces shrinkage. Sand also increases the volume of mortar. It also strengthens the mix due to its superior mechanical properties like shear and tensile strength.

TRANSITION ZONE comes into effect when shearing stress exerted on the cement paste by the aggregate particles during mixing, which cause the water to separate from the cement particles. The result is a narrow region around the aggregate particles with fewer cement particles, and thus more water. This is called the interfacial transition zone, abbreviated ITZ.

. The thickness of the layer ranges from 20 to 100 μm. There are often $Ca(OH)_2$ particles oriented along the aggregate particles. The porosity of the transition layer is larger than that of the hardened cement and a porosity gradient with the decreasing character in the direction away from the aggregate particles could be observed [6,7].The character of the geopolymer – aggregate boundary is quite different.

II. EXPERIMENTAL WORK

2.1 Materials

2.1.1 Fly Ash_ - Fly ash is byproduct material and is produced by combustion of pulverized coal in power plant. The particle sizes in fly ash vary from less than 1 µm (micrometer) to more than 100 µm with the typical particle size measuring under 20 µm. Only 75% of the particles by mass are larger than 45 µm[8]. Class F grade fly ash was used for this purpose. The chemical composition of this fly ash is given in table-1.

Table-1Chemical composition of the fly ash (Mass %)

Oxide	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	SO_3	P_2O_5	Loss of ignition
Mass (%)	58.15	27.5	4.6	2.05	3.45	0.98	1.03	0.85	Nil	0.7	0.8

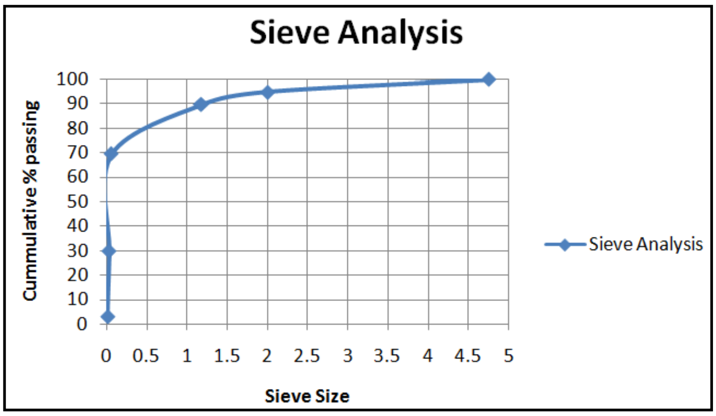
As per ASTM C 618 (AASTHO M 295), if the fly ash posses low-calcium (<10%CaO) with usually <5% carbon content, then that fly ash is categorized as Class F material. Usually the carbon content is less than 5%, but sometime it may be as high as 10%.

2.2.2 Alkaline Activator_– The alkaline activator liquid was the combination of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3). NaOH pellets were dissolved in distilled water and left it for 24hrs. Then Na_2SiO_3 was added to the NaOH solution , and kept for 3 hours. After this the solution was added in the dry mixture of fly ash and sand.

2.2.3 Fine Aggregate - River sand was used as the fine aggregate. It was made as saturated surface dry condition (SSD) before making the geopolymer mortar. The fineness modulus of the sand was 3.86. According to IS 383-1976, the particle size distribution showed that the sand was of zone II. The sieve analysis report of this sand is as follows

Is Sieve Size (Mm)	Wt. Retained (Kg)	Cummulative Wt. Retained	Cummulative % Retained	Cummulative Passing	Total	Fm (%)
4.75	0	0	0	100	386.31	3.86
2	79	79	5.26	94.74		
1.18	77	156	10.4	89.6		
0.06	304	460	30.66	69.34		
0.03	594	1054	70.26	29.74		
0.015	403	1457	97.13	2.89		
PAN	43	1500	100	0		

Here is the graphical representation of the sieve analysis report i.e the GSD curve:



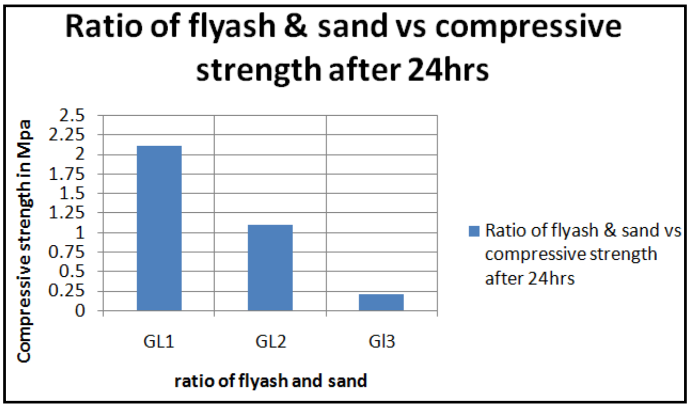
III. RESULTS AND DISCUSSION

1.1 Compressive strength

Compressive strength is one of the most important mechanical properties of fly ash based geo-polymer mortar. Compressive strength test is performed on cubical shape specimen. The size of the cube is 75mmx75mmx75 mm. which are prepared in moulds of cast iron and then they are heated in oven at 85^0C for 24hours and 300^0C for 72hours. After this, they are cooled to room temperature and crushed in compressive strength testing machine, and lastly there results are noted.

Results for the Samples of 85^0C are tabulated below:

Specimen Name	Ratio of fly ash: Sand	Compressive Strength after 24hrs of heat curing (MPa)
GL1	1:1	2.10
GL2	1:2	1.10
GL3	1:3	0.20



It can be concluded from the graph that after heating the three cubes for about 24hours, the compressive strength of the cubes decreases with increase in the percentage of sand keeping percentage of fly ash constant.
Thus it is economical to use fly ash with sand with 1:1 ratio, where a higher strength is obtained.
While in case of concrete, Compressive Strength increases with increase in the ratio of sand or coarse aggregate.

1.2 Sorptivity

Sorptivity is that property which denotes the capacity of a medium to absorb liquid by capillary movement [9]. If the porosity of the material falls, then the sorptivity of the material also drops but the durability and tensile strength of the material increases. The test of sorptivity requires calculation of water sorption with time [10]. In the graph below cumulative absorption of water is plotted against square root of time.

The samples GL1, GL2, GL3, GH1, GH2 and GH3 are rested on small supports in such a way that only the lowest 2mm to 5mm of each cube is submerged. It shows an increase in the mass of the cube with time which is recorded. A relation is obtained here which is

$I = S\sqrt{t}$

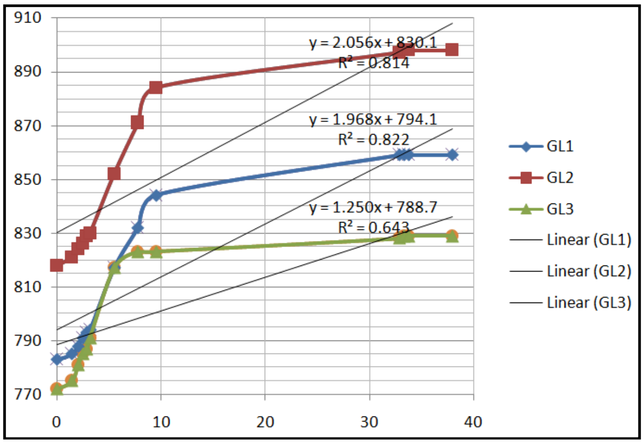
Where,

I=increase in mass per unit area (gm/mm square) / density (gm/mm cube) of water

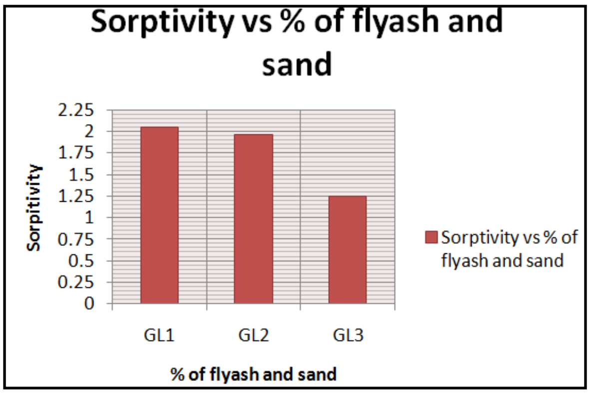
T=time i.e. measured in minutes where mass is determined

S=Sorptivity in mm/min to the power 0.5

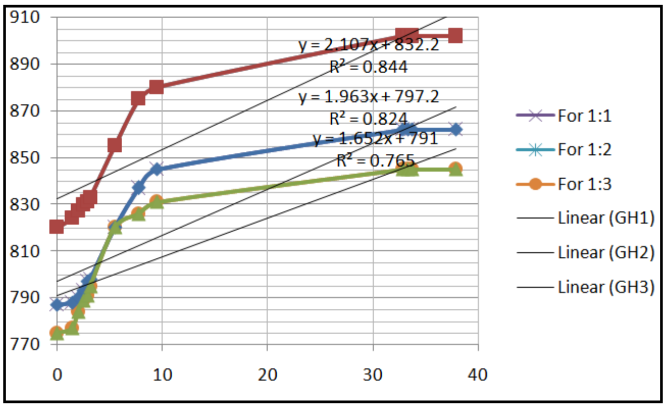
The graph of sorptivity for the cubes GL1, GL2 & GL3 are as follows:



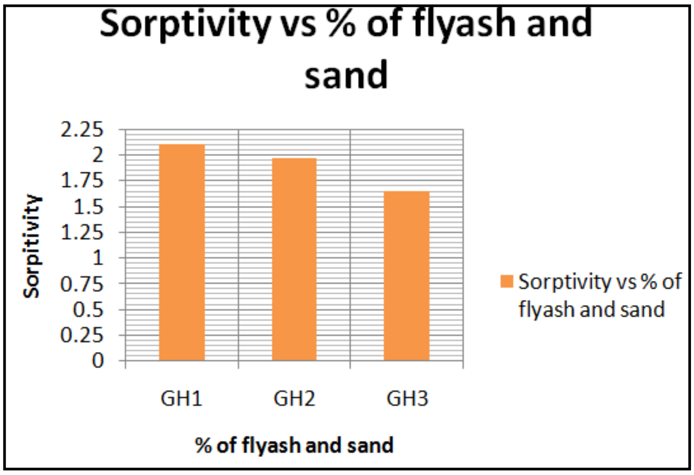
From the graph it can be concluded that the value of absorption increases with the increase in time, but after 24hrs the value does not change, and thus the graph becomes linear. This is because the mortar cube reaches its saturation point and its pores gets filled up by water molecules.



From the chart, it can be seen that the Sorptivity value decreases with the increase in the percentage of amount of sand. This is because due to the increase in the amount of sand, the intermolecular spaces of the fly ash decreases, and hence the amount of water also gets decreased.
The graph of sorptivity for the samples GH1, GH2 & GH3 are as follows:



From the graph it can be concluded that the value of absorption of water for the mortar cubes heated at 300^{0}C increases with the increase in time, but after 24hrs the value does not vary, and therefore the line becomes linear. This is because the mortar cube reaches its saturation point and its pores gets filled up by water molecules.



From the chart, it can be seen that the Sorptivity value decreases also with the increase in the percentage of amount of sand for 300^{0}C.

1.3 Apparent Porosity

This test method helps in developing the values required for establishing relations between volume and mass for mortar. This method helps in the determinations of density, percentage of absorption of water and percent of voids found in hardened mortar. Here this test is performed as per ASTM C 642-97[45].

Calculation:
Bulk density, dry = $\{W_1/ (W3- W_4)\}$ Þ
Bulk density after immersion = $\{W_2/ (W3- W_4)\}$ Þ
Bulk density after immersion and boiling = $\{W_3/ (W3- W_4)\}$ Þ
Apparent density = $\{W_4/ (W_4- W_1)\}$ Þ
Apparent Porosity (%) = $\{(W_3-W_1)/ (W_3-W_2)\}$ x 100
Where,
Mass of oven dried sample in air (gm). = W_1
Mass of surface dry sample in air after immersion (gm) =W_2
Mass of surface dry sample in air after immersion and boiling (gm) =W_3
Density of water (1 gm/cm^3) = Þ

The results of the apparent porosity and apparent density for the test specimens heated at 85^{0}C have been tabulated below.

Specimen	***W₁***	***W₂***	***W₃***	***Apparent Density***	***Apparent Porosity***
1:1	225	418	452	1.99	6.68
1:2	220	674	755	1.41	6.60
1:3	90	243	271	1.49	6.46

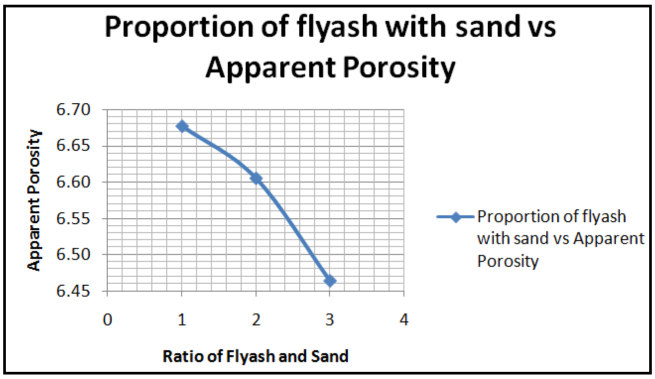


Fig.

Thus from the figure it can be concluded that the volume of permeable pore space (apparent porosity) decreases with the increase in the amount of the sand.

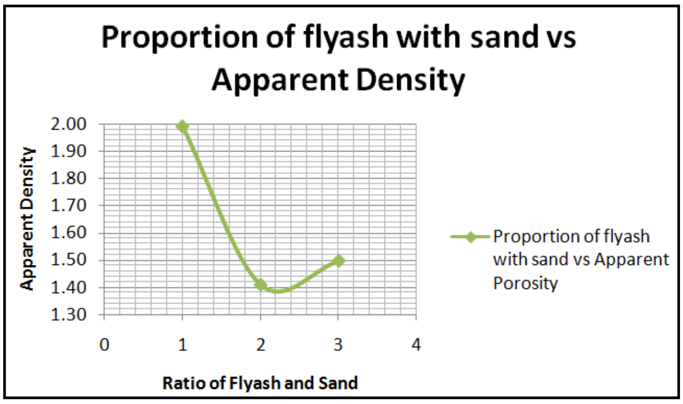


Fig.

Thus from the figure it can be concluded that the apparent density decreases with the increase in the amount of the sand.

The results of the apparent porosity and apparent density for the test specimens heated at 300^{0}C have been tabulated below.

Specimen	***W₁***	***W₂***	***W₃***	***Apparent Density***	***Apparent Porosity***
1:1	230	430	467	2.15	6.41
1:2	250	685	765	1.57	6.44
1:3	100	250	280	1.67	6.00

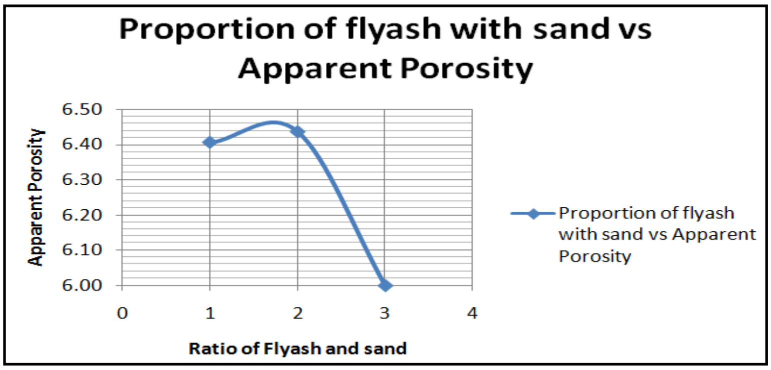


Fig.

Thus from the figure it can be concluded that for a higher temperature of 300^0C, the apparent porosity decreases with the increase in the amount of the sand.

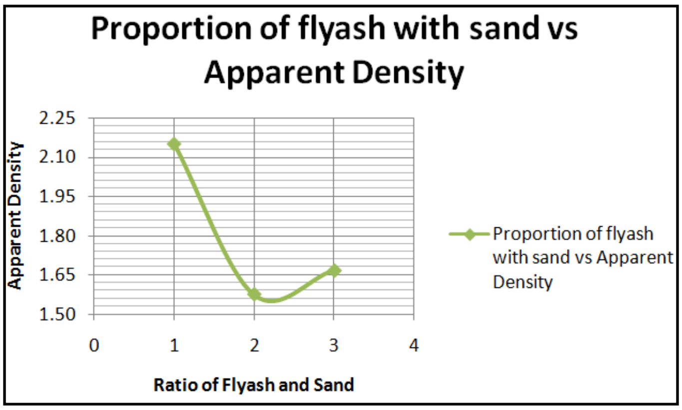


Fig.

Thus from the above figure it can be concluded that for a higher temperature of 300^0C, the apparent density also decreases with the increase in the amount of the sand.

1.4 Water Absorption

Water absorption is one of the important characteristics to know the hardened property of fly ash based geo polymer mortar. Water absorption has been determined for three types of mixes of fly ash to sand content (1:1,1:2,1:3) and hence to determine the comparability. The water absorption can be determined by the following empirical formula—

$W_a = \frac{W_{sub} - W_s}{W_s} \times 100$

Where,

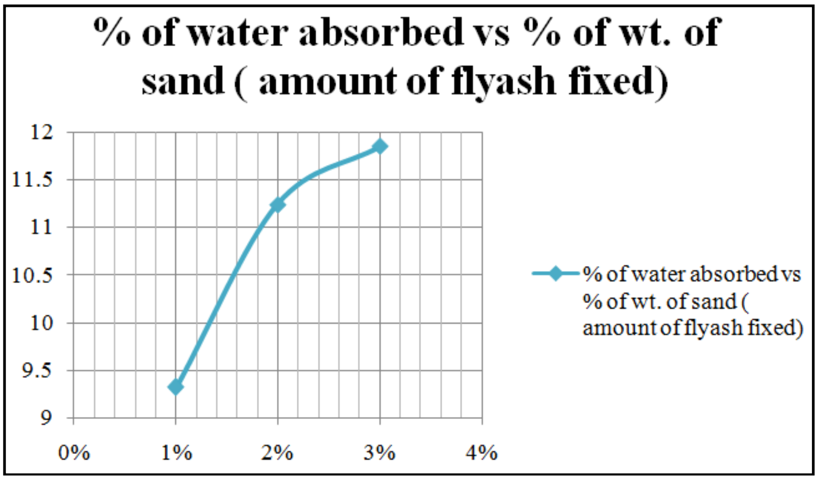
W_a= Water absorption in percentage

W_{sub} = Weight of the submerged sample after 24 hours in gram

W_s=Weight of the dry sample in gram

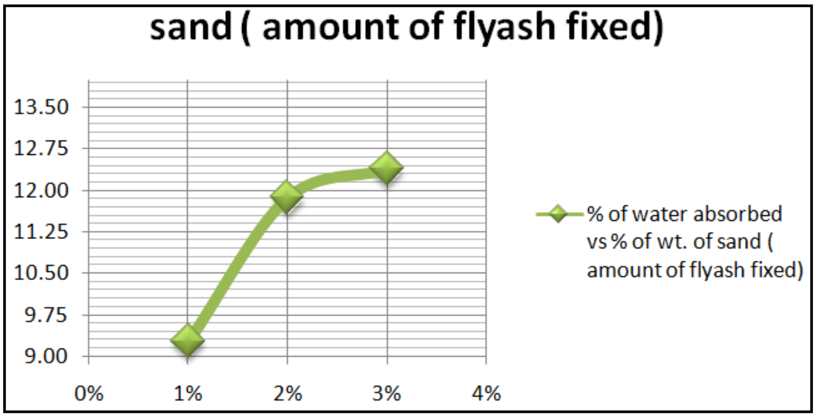
The results for the cube at 85^0C are as tabulated below:

Dry wt. sample (W_s)	**Wt. after 24hrs (W_{sub})**	**% of water absorbed (W_a)**
611	668	9.32
747	831	11.24
877	981	11.85



Hence from the graph it can be concluded that % of water absorption increases with the increase in the amount of sand, keeping % of fly ash constant. This is due to the reason that sand can absorb lots of amount of water rather than fly ash, so as amount of sand increases, amount of absorption of water increases.
The results for the cube at 300^0C are as tabulated below:

Dry wt. sample (W_s)	**Wt. after 24hrs (W_{sub})**	**% of water absorbed (W_a)**
615	672	9.27
751	840	11.85
881	990	12.37



IV. CONCLUTION

Mortar cube having ratio 1:1 (sample GL1) exhibits higher compressive strength. The sorpitivity value is high for fly ash and sand ratio (1:1, sample GL1) for cubes at lower temperature as well as higher temperature. Higher the amount of sand, both apparent porosity and apparent density decreases. The value of water absorption increases with the increase in the amount of sand.

ACKNOWLEDGEMENT
We would like to express our special thanks of gratitude to our professor Debabrata Dutta who helped us throughout the project.

REFERENCE

[1] Qian Zhu, CO_2 abatement in the cement industry, June 2011
[2] M.I Abdul Aleem, PD Arumairaj "Geopolymer Concrete- A Review", International Journal of Engineering Sciences & Emerging Technologies, Feb 2012
[3] Davidovits,J "Pyramids of Egypt made of man-made stone, myth or fact?" Symposium on Archaeometry 1984

[4] Hardjito, DS Wallah, DMJ Sumajouw and BV Rangan "On the development of fly ash – based geopolymer concrete" ACI Materials Journal, Vol-101, no 6, 2004
[5] Rangan, BV "Low-calcium, fly-ashbased geopolymer concrete" Concrete Construction Engineering Handbook, Taylor and Francis Group, 2008
[6] Diamond S.: The microstructure of cement paste in concrete. Proc. 8th Int. Congr. Chem. Cement, Rio de Janeiro, 1986, p. 122-147
[7] Maso J.C.: The bond between aggregate and hydrated cement paste. Proc. 8th Int. Congr. Chem. Cement, Rio de Janeiro, 1986, p.378-380
[8] Design and control of concrete mixtures . EB001. Chapter -3, p. 58
[9] Philip, John R (1957). "The theory of infiltration: 4. Sorptivity and algebraic infiltration equations". *Soil Science* **84**: 257–264
[10] Debabrata Dutta and Somnath Ghosh "Durability study of geopolymer paste blended with blast furnace slag"