DEVELOPMENT OF PROCESS FOR CREATION OF LOW- COST ARTIFICIAL SAND FROM FLY ASH

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Abstract

In this project the development of artificial sand is done by geopolymerization. Alkali solution of sodium hydroxide and sodium silicate were used for geopolymerizing fly ash. Fly ash granules are obtained from granulation process and these granules are the product as artificial sand. The development of this artificial sand is an alternate to the natural sand and economical compared to other artificial sands such as M-sand, there is a vast scope for the development and research of the proceeding project on fly ash. The existence of this artificial sands arised due the scarcity of natural sand and depletion of environment. So the development of sand using fly ash, which is a residual from thermal power plants, is eco-friendly. Geopolymer concrete (GPC) is the most important construction material. It is composed of fly-ash, fine aggregate, coarse aggregate and alkaline solution. Geopolymers are highly alkaline binders used as an alternative for the replacement of OPC in the manufacture of concrete. The advantages of using geopolymers are that they impart excellent mechanical strength, help in reducing carbon di-oxide emission and helps in achieving good durability properties. Common river sand, which is the most commonly used fine aggregate, is expensive due to excessive cost of transportation from natural sources. . In addition, the increasing demand for river sand, are leading to environmental effects, thus developing an urgent need to replace river sand with an alternative construction material. In such a situation the Geopolymer sand (GPS) can be an economic alternative to the river sand in concrete.

Keywords: Geopolymer, Fly ash, alkaline solution, Geopolymer sand, Mechanical strength

Introduction

Every year the concrete production is increasing, throughout the world. With the increasing demand for concrete the demand for natural aggregates is also increasing, leading to the scarcity and the rise in the cost of these natural aggregates, which necessitates to pave way for the alternative sources to replace these natural aggregates. Various alternatives such as fly ash, bottom ash, crusher dust, have been studied by researches to replace natural sand, however these alternatives were able to replace natural sand only partially. In order to meet the increasing demand of natural aggregates this research focused on utilizing fly ash to produce geopolymer fly ash sand (GFAS), by mixing fly ash with the geopolymers as the production of fly ash from thermal power plants is increasing day by day leading to the disposal problems and environmental problems. Thus, by utilizing fly ash for the manufacture of aggregates it will help in overcoming the twin problem of the country. An effort to make environmentally sustainable sand is to develop inorganic alumino silicate polymer synthesized from materials of geological origin or by- product materials such as fly ash that are rich in silicon and aluminium. Fly ash one of the source materials for geopolymer binders is available abundantly worldwide but to date its utilization is limited. The spherical shape of fine particles of fly ash gives better mix with cement. Fly ash was collected from the thermal power plant and alkali compounds were collected commercially. Granulator is fabricated for the conduction of experiment and the experiments were conducted on synthesizing fly ash granules at different molarities of alkali solution in the granulator. The synthesizing of granules is performed for certain period of time at which granules were formed uniformly. In case excess alkali solution in the granulator some quantity of fly ash is added by weight. The weight of alkali solution consumed is taken.

Geopolymer

Geopolymers are an inorganic alumino silicate base, formed by mixing of waste materials having glassy silica and alumina content in an alkaline activator solution to produce an alumina-silica chain which has binding properties.

Alkaline Activator

The alkaline activator is a catalyzing medium wherein the glassy compositions of the source materials convert into a solid compound having robust binding properties.

Literature Review

A brief review of literature, which deals with the study on developing the economical artificial sand using fly ash is presented in this chapter.

Sudhakar and Indira (2014)

Using geopolymers in place of ordinary Portland cement is very benefitable as it releases less carbon dioxide and less energy consumption. Geo polymerization of fly ash amorphous silica mixtures is employed to produce fine aggregates as a possible replacement to river sand. Synthesis of fly ash geopolymer sand and comparison of properties of fly ash sand with river sand. Geopolymerization of fly ash amorphous silica mixture in a 10M NaOH solution at 100^0C for 7 days produced fine aggregates value of 6 to 15 degree. The RS–M and FAPS–M specimens developed similar 28-day compressive strengths of 12.2 and 11.6 MPa, respectively.

Nagajyothi and Elavani (2016)

Rapid increase in urbanization and demand for Portland cement and natural sand has risen the scarcity and detorsion of natural sand, also became costlier. Preparation of cement exhales lot of Co_2 which too much in atmosphere is hazardous. So, the geopolymer concrete material having low calcium fly ash is best alternative than cement and M sand. Partial replacement of river sand by M sand with alkaline solution of NaOH andNa_2si0_3 for finding the properties of compressive strength, tensile strength and flexural strength. After assessment the finding were when proportion of MS increase workability also increases. So, the usage of superplasticizers is not needed.

Agarwal et. al (2017)

Geopolymers are highly alkaline binders used as an alternative for the replacement of OPC in the manufacture of concrete. The advantages of using geopolymers are that they impart excellent mechanical strength, help in reducing carbon di-oxide emission and helps in achieving good durability properties. In addition, the increasing demand for river sand, are leading to environmental effects, thus developing an urgent need to replace river sand with an alternative construction material. Geopolymerization of fly ash in 10 M NaOH and Na2SiO3: NaOH= 1.8:1 solution at 100°C for one hour produced geopolymer fly ash aggregate (GFAS) to produce an alternative replacement for river sand. The specific gravity of GFAS was 1.82 indicating that these particles were light weight. The properties of concrete such as compressive strength and flexural strength were also studied by replacing river sand with GFAS in concrete. It was observed that the mechanical strength of the GFAS was nearly same as that of the river sand concrete, thus indicating GFAS can be used as an alternative material to replace river sand in concrete. The compressive strength properties of the GFAS Conc. Was 95.1% at 28 days as and nearly 100% at 56 days as compared to the NRS Conc. indicating increase in the compressive strength with the increase in the curing time for concrete cubes.

The flexural strength result of GFAS Concrete was 97.74% strength at 28 days and98.81% strength.

Sharma et.al (2019)

Natural sand properties were compared with manufactured sand Know as M sand or crushed sand, to know the properties and improvements. It was clear that M sand compared to natural sand has given greater strength parameters after final curing in construction, also natural sand has impurities like shells, mica etc. where as in m sand there are no variety of impurities besides dust or very finer particles. To make things more Cheaper and better to environment synthesis of fine aggregate from fly ash of class F is done by geo polimerization reactions where aluminosilicate form covalent bonds gets attached around the fly ash fine particles making granules acting as fine aggregate. The finding out of this synthesis is water absorption of C-GFA IS 6% AND F-GFA IS 5.5% which is higher compared to natural sand and M-sand (1 and 0.9%).

Simon (2019)

The OPC cement has become a monopoly in the field of construction as there were no alternatives but OPC consumes lot of energy and releases out carbon di-oxide into atmosphere. Geo Polymer composites are possible alternates to OPC and otherblended cements. This is due to the high early strength and improved durability evidenced by resistance against acid and sulphate attack, apart from environmental effects. The material properties were studied based on their properties reference mix M25 and M30 were designed to conduct the assessment. The workability for all the Geopolymer concretes is twice when compared to reference concrete by increasing the time and temperature of steam curing the strength of geopolymerconcrete increases.

Methodology

A detail methodology for development of process for the creation of artificial sand is conferred in the following sections.

Preparation of alkaline solution

The sodium hydroxide pellets and sodium silicate solution were collected. The sodium hydroxide solution is prepared for molarities of 10M & 12M by dissolving pellets in distilled water. The solution of sodium hydroxide and sodium silicate is prepared for different ratios (1:1, 2:1, 3:1, and 4:1)

Characteristics of fly ash

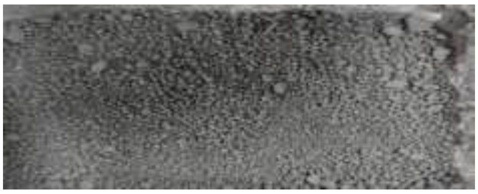
Class F fly ash is collected and oven dried. The weight of fly ash is taken to a ratio of 3:1 to that of alkali solution Then the required fly ash is sieved through Is sieve size of 4.75mm. The granulator used in this project is fabricated by fixing a disc at inclined position at a certain height the disc is composed of metal of certain thickness joining the center. The granulator is run by a motor of rpm of 1425 and 50 hertz frequency making the disc at 25 revolutions per minute.

Synthesis of granules in granulator

The fly ash is poured into granulator and the granulator turned on. The alkali solution is spread on to the dry fly ash uniformly with respect to time with the helpof sprayer.

Formation of granules:

(i)Ratios: Fly ash/Solution (10M NaOH and Na_2Sio_3)



(a) Granules @ 2.25:1

(b) 3:1 (solid to liquid)

(c) 3.37:1 (solid to liquid)

(d) 3.6:1 (solid to liquid)

Fig(1): Formation of granules at different fly ash to alkaline solution ratios(a)@2.25:1(b)@3:1 (c) 3.37:1 (d) 3.6:1. These are obtained granules for 10M NaOH solution

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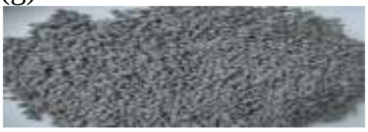
(ii)Ratios: Fly ash/Solution (12M NaOH and Na2Sio3)

(e)  3.33:1 (solid to liquid)	(f)  4.45:1 (solid to liquid)
(g)  5:1 (solid to liquid)	(h)  5.3:1 (solid to liquid)

Fig(2): Formation of granules at different fly ash to alkaline solution ratios: (e)@3.33:1 (f)@4.45:1 (g) 5:1 (h) 5.3:1. These are obtained granules for 12M NaOH solution

Tests on GP sand: After 24 hours, the granules are removed from oven and different tests are conducted.

- Specific gravity (IS:2386-part-3 1963)
- Sieve analysis (IS 2720-Part (IV)- (1985)
- Direct shear test (IS:2720-PART-13-1986)
- pH test (IS:2720).
- Electro conductivity test (IS 1476-2000)

Analysis of results: After the tests, based on observations the graphs are plotted and results and conclusion are determined.

Graulation Process:

Chemical Properties of Granules formed:

After formation of granules for different molarities and different alkali ratios the chemical properties obtained are tabulated in table no1. The pH values of synthesized granules were increased from 10M to 12M alkali solutions, the values were increased as the ratio of alkali solutions increased for the different molarities respectively.

Table 1: Properties of FAPS material (10M & 12M of NaOH and Na2SiO3)

Ratio of NaOH to NA_2SiO_3	pH value		EC(ms/cm)@29°C		TDS(ppm)@28.3	
	10M	12M	10M	12M	10M	12M
1:1	11.56	12.48	4.72	5.14	3.48	3.62
1:2	11.62	12.52	5.20	5.76	3.45	3.72
1:3	11.68	12.72	5.53	6.14	3.40	3.84
1:4	11.86	12.86	5.96	6.62	3.76	4.12

The synthesized granules consumed alkali solution and granulator revolved for certain duration of time The values were tabulated in the table no .The alkali solution consumed for 10M solution is more than 12M solution .The formation of granules were for these molarities were taken similar duration.

Table 2: Synthetic sand preparation for 10M NaOH and Na2SiO3

Sodium to Silicate ratios	Solid to solution ratio		Volume of alkaline consumed(grams)		Fly ash (grams)		Granulation Time (Minutes)	
	10M	12M	10M	12M	10M	12M	10M	12M
1:1	2.25:1	4.3:1	400	320	900	1600	35	40

2:1	3:1	4.22:1	300	236	900	1600	35	35
3:1	3.37:1	5:1	266.66	180	900	1600	35	45
4:1	3.6:1	5.22:1	200	146	900	1600	40	40

The alkaline activator solution is prepared for 10 molarity for different ratios of sodium hydroxide and sodium silicate (1:1 ,2:1 ,3:1, 4:1). The sodium hydroxide offixed sample of 200gm is taken. In each trial different ratios of sodium silicate is taken. The alkaline activator solution is prepared by dissolving 200gm NaOH in 500ml of distilled water. From this 200gm of NaOH is taken and mixed with different ratios of Na_2SiO_3

Preparation of granules:

Alkaline activator solution is taken in spray jar and sprinkled uniformly. After 35minutes, granules are formed in small rounded shape. The granules weight is taken and they kept in oven dry for 24hr. After 24hrs the granules are taken from oven and weight is taken PH, EC, Sieve analysis and direct Then 900gm of fly ash is taken. Fly ash is poured in granulator and initial time is noted. The shear strength tests are conducted for each sample.

Experimental Investigations

Commercially available NaOH & Na_2SiO_3 from Narmada chemical industries, Kukatpally and fly ash were collected from were used in the present study.:

Materials are classified based on the engineering properties,

Specific Gravity: (IS:2386-part-3 1963).

Specific gravity varies with temperature and pressure. It is important that temperature and pressure of each substance is same so that the density values represent the properties under the same condition. Empty clean and dry density bottle taken and weighed it (w_1). Oven dried granules are taken into empty bottle and weighed it (w_2). In granules bottle fill the bottle with water and leave it for 2 hours without disturbing, and weight of contents taken after 2 hours (w_3). Empty bottle is filled with water and weight is taken (w_4). The process is repeated for 2-3 times and average values are taken.

Specific gravity =(w2-w1)/[(w2-w1) -(w3-w4)]

Sieve Analysis: [IS 2720-Part (IV)- (1985)]

Sieve analysis is carried out to know the particle size distribution of granules of fly ash formed by granulator. As the granules are oven dried after removing from granulator so dry sieve procedures are done. Take the weight of granules after dried in oven, Place the sieves from 4.75millimeters to 75micron in such way that large opening sieve is placed on top and least size on bottom. place the pan at bottom and cap after pouring the granules into the sieve system. Place the sieve system in mechanical shaker for 5mins, here use a stop watch. After the process take the weight of retained granules on each sieve and draw a graph on particle weight retained vs sieve sizes, to determine coefficient of uniformity (c_u) and co- efficient of curvature (c_c). The same procedure is done for all the ratios of alkaline activator.

Co-efficient of uniformity (c_u) = D60 / D10

Co-efficient of curvature(c_c) = D_{30}^{2} / D10 * D60

D60, D30 and D10 are effective size of particles corresponding to 60%,30%,10% finer in the particle size distribution graph D60 means 60 percent particle are finer than this size D30 means 30 percent particle are finer than this size D10 means 10 percent particle are finer than this size.

Direct Shear Test: [IS:2720-PART-13-1986] The direct shear test is used to determine the shear strength of granules and for cohesion and angle of friction. The oven dried granules specimen are placed in the direct shear box apparatus. The shear box is set to direct shear device with set of conditions and applied a predetermined normal stress until the specimen failure. The pins are removed that lock the shear box and values are noted. The is repeated for different molarities with different ratio. Each ratio is repeated for 2-3 times and average values are taken.

Crushing strength, pH: [(IS:2720)].The pH test is used to determine the solution is whether acidic or alkaline. The oven dried granules are taken and dissolved in distilled water. The water filtered with filtration paper. The pH of water is determined by using pH meter. The probes of pH and temperature are immersed in water, the values of pH and temperature are shown in the screen.

Electrical conductivity: [IS 1476(2000)] The test is conducted to determine the dissolved substances, chemicals and minerals present in the water. Oven dried granules are dissolved in water. The water is filtered by using filter paper. This test is determined by using electro conductivity meter. At first stage, the calibration is done for the instrument. At second stage, the conductivity probe and temperature probe immersed in solution. The temperature and conductivity of solution shown in the screen are noted.

Results And Discussion

A detailed discussions on the results obtained from the different experimental worked are conferred in the following sections.

Properties of Fly ash and Alkali Solutions

The fly ash properties were obtained by conducting following experiments as tabulated in table no 4.1 the specific gravity of fly ash obtained is 2.03 whereas for natural sand the value vary from (2.3-2.8) .the specific gravity of granules obtained vary (2.3-2.5),the water absorption of fly ash is .the water absorption for fly ash granules obtained .the pH of fly ash 8.68 which indicates that the fly ash is basicin nature .the electrical conductivity obtained was approximately 4 which is relative to sea water and has the similar conductivity as that of sea water.

Direct Shear Test: [IS:2720-PART-13-1986]

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Table 3: Fly Ash Properties

S No	Properties	Values obtained
1	Specific gravity	2.03
2	Water absorption (%)	18.78

3	pH	8.68
4	TDS (ppm)	0.361
5	EC (mS)	4.090

Properties of Alkali Solutions

The properties of NaOH and Na_2SiO_3 used in the experiments conducted aretabulated as in the below table No.

Table 4: Properties of Alkali Solutions

	NaOH	
S No	**Components**	**Percentage of components (%)**
1	Min. Assay (quality of thecompound)	98
2	Carbonate (as Na2CO3)	1
3	Chloride(cl)	0.01
4	Sulphate (SO4)	0.003
5	Phosphate (PO4)	0.002
6	Silicate (Sio2)	0.01
7	Total nitrogen(N)	0.0005
8	Heavy metal (Pb)	0.0005
9	Iron (Fe)	0.001
10	Aluminum (Al)	0.001
11	Arsenic (As)	0.0004
12	Potassium (K)	0.1

The values of the specific gravity of FAPS material of 10M & 12M alkali solution are tabulated in the table no .The values of specific gravity were increased as the molarity of the alkali solution increases .The values for different ratios are obtaineddifferently.

Table 5: Values of specific gravity of FAPS material (10M & 12M NaOH and Na2SiO3)

S. No	Description	Sodium to Silicate Proportions			
		1:1	1:2	1:3	1:4
1	Determination for 10M ofNaOH and Na_2SiO_3	2.55	2.52	2.19	2.78
2	Determination for 12M ofNaOH and Na_2SiO_3	2.69	2.67	2.75	2.38

Sieve Analysis : Sieve analysis was conducted for the synthesized granules from fly ash, at 10M, 12M alkali solutions.The values of coefficient of uniformity and coefficient of curvature were obtained from the graph. The values coefficient of curvature was increased from 10M to 12M alkali solution upto 3:1 alkali solution anddecreased for 4:1ratios.The coefficient of uniformity increased for all ratios from 10M to 12M except 3:1 ratio.

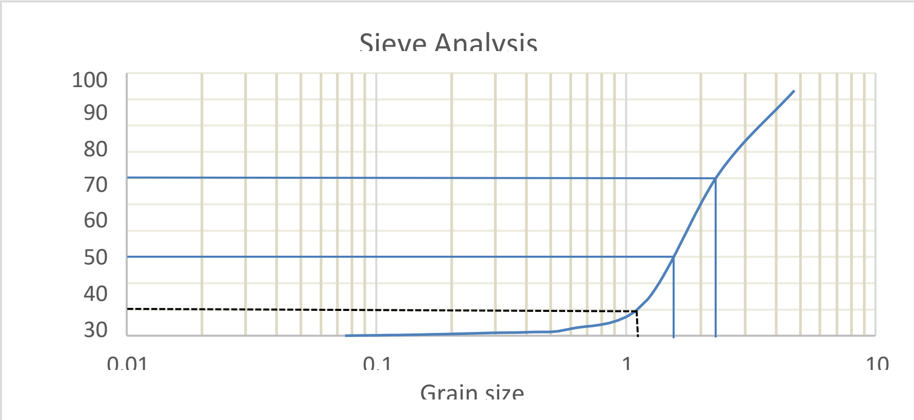

Fig 3: Sieve analysis of FAPS (6M NaOH and Na2SiO3)

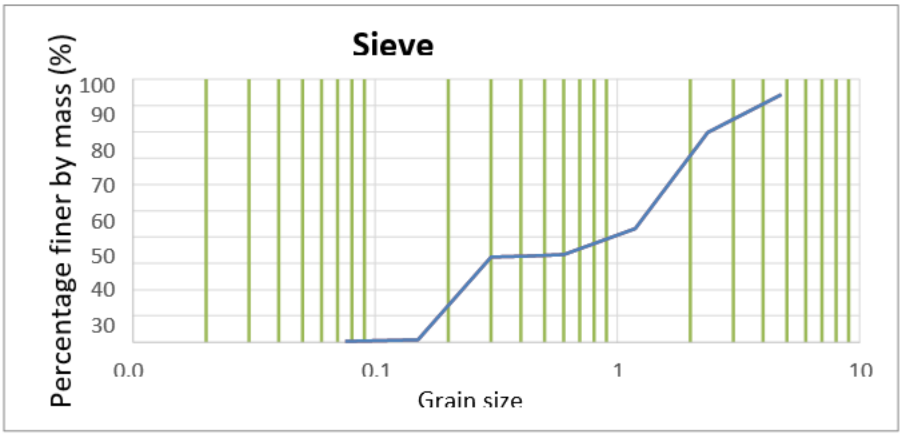

Fig 4: Sieve analysis of FAPS (6M NaOH)

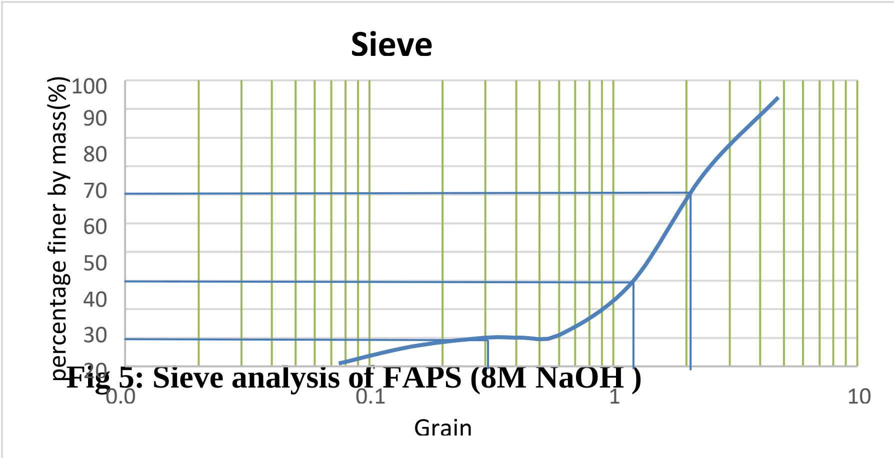

Fig 5: Sieve analysis of FAPS (8M NaOH)

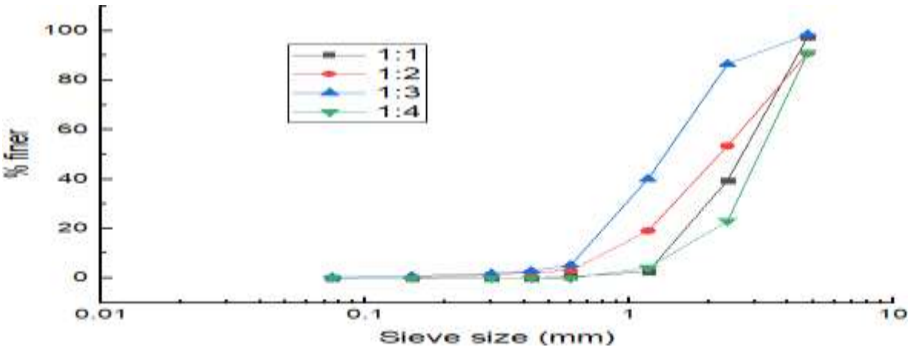

Fig 6: Sieve analysis of FAPS (10M NaOH and Na_2SiO_3)

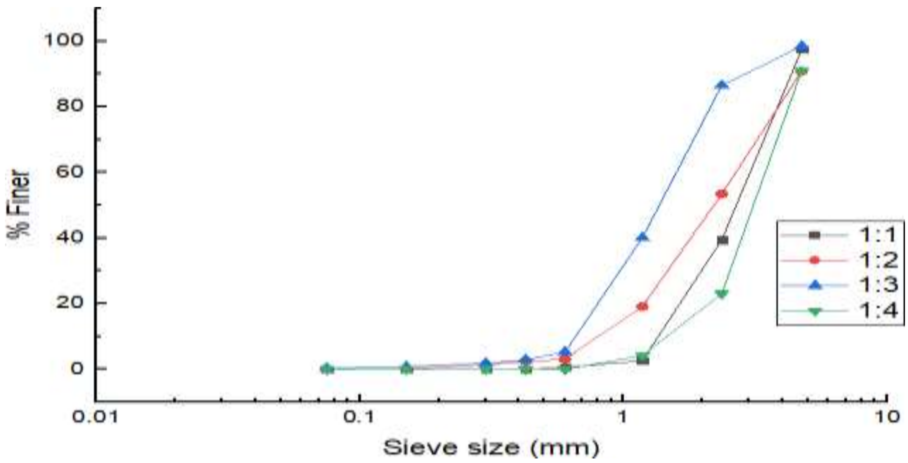

Fig 7 : Sieve analysis of FAPS (12M NaOH and Na_2SiO_3)

Coefficient of curvature(cc) and coefficient of uniformity(cu)

The coefficient of curvature and coefficient of uniformity values obtainedare tabulated in the table no 6.

Sodium to silicate proportions	Coefficient of curvature (Cc)		Coefficient of uniformity (Cu)	
	10M	12M	10M	12M
1:1	2.28	2.63	0.814	1.08
2:1	2.0	3.26	0.80	1.02
3:1	1.6	2.48	0.96	0.74
4:1	3.0	1.83	0.86	1.06

Direct Shear Test

Results obtained from direst shear test on samples different rations (1:1, 2:1,3:1,4:1) were presented below. Generally, coulombs equation is used for computing the shear parameters:

For clayey soils;

S= C+ σ tan(φ)

For sands;

S= σ tan(φ)

Where S= shear strength of soil (kg/cm^2)C= cohesion (kg/cm^2)

σ = Normal load applied on specimen (kg/cm^2)φ = Angle of resistance (degrees)

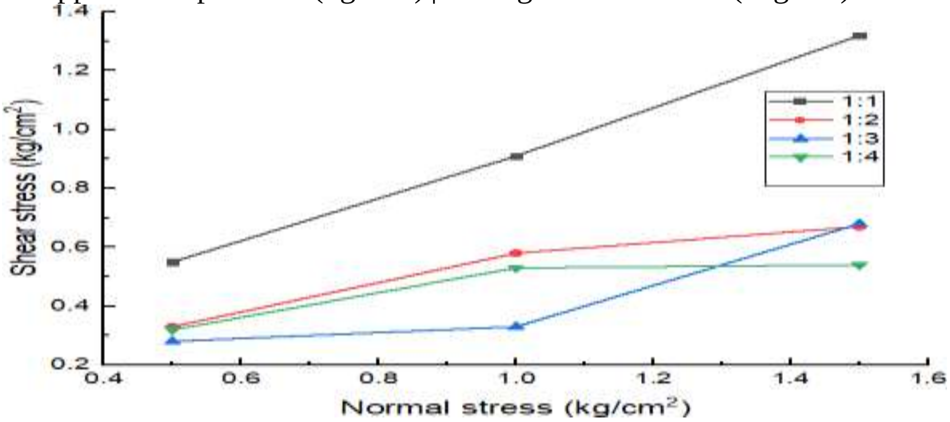

Fig 8: Direct shear test of FAPS (12M NaOH and Na2SiO3)

Table 7: Values of frictional angle for FAPS (10M and 12M NaOH andNa2SiO3)

Sample No.	Ratio of NaOH & Na2Co3	Friction angle of granules formed10M (φ)	Friction angle of granules formed 12M(φ)	NaturalSand
1	1:1	38 º	22.91	30 º - 36 º
2	2:1	39 º	8	
3	3:1	36 º	44	
4	4:1	37 º	15	

Table 8 : Cost Estimation

Silicate tosodium ratios	(Flyash/Alkaline Solution)	Volume of alkaline consumed (grams)	Fly ash (grams)	Granules formed	Costper kg (Rs.)	Granulation Time (Minutes)
1:1(200:200)	2.25:1	400	900	1100	225	35
2:1(100:200)	3:1	300	900	950	150	35
3:1(66.6:200)	3.37:1	266.66	900	900	125	35

4:1(50:200)	3.6:1	200	900	870	100	40
1:1(240:240)	3.33:1	320	1600	1650	275	40
2:1(120:240)	4.45:1	236	1600	1620	175	40
3:1(80:240)	5:1	180	1600	1450	135	40
4:1(60:240)	5.3:1	146	1600	1380	125	45

Conclusion

- Geopolymerized sand had a specific gravity of 1.86 which was less than compared to natural sand (2.67), indicating geopolymerized sand are light weight particles.
- The particle size distribution curve of geopolymerized sand confirmed to zone-1, which was similar to that of river sand.
- The water absorption of 9.21% was absorbed in case of geopolymerized sand whilenatural river sand had 0.82% water absorption, indicating geopolymerized sand areporous in nature.
- Greater Durability. Artificial-Sand has balanced physical and chemical properties that can withstand any aggressive environmental and climatic conditions as it has enhanced durability, greater strength and overall economy. ...

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