International Journal of ChemTech Research
CODEN (USA): IJCRGG ISSN: 0974-4290
Vol.8, No.2, pp 738-745, 2015

Strength Charecteristics of Saw Dust Ash Based Geopolymer Concrete

T.R.Praveen Kumar, Sudheesh.C, Sasi Kumar.S

Department of Civil Engineering, Sathyabama University, Chennai-119,India

Abstract: In this Research work , experimental work has been carried out which is used to check the feasibility of using saw dust ash as partial replacement to fly ash in the production of Geopolymer concrete. In this study the chemical composition and physical properties of Saw dust ash was investigated first. The results showed that the saw dust ash mixture is a very good pozzolan material as per IS 3812:2003.Hence it was used to replace fly ash by 5%,10%,15%,20% in the production of Geopolymer concrete. The compressive Strength was measured by testing standard cubes at 7 days and 28 days. The specimens were tested after heat curing it at 60^{o}C. It was found that 5% replacement of Saw dust ash gave satisfactory results when compared to other mixes. Hence it is suggested to use Flyash replaced partially up to 5% by Saw dust ash to produce an economical geopolymer concrete.
Keywords: saw dust ash, Geopolymer, Flyash, workability.

I. Introduction

Concrete is the second most consumed substance on Earth after water. Cement is the primary ingredient in concrete, which in turn forms the foundations and structures of the buildings we live and work in, and the roads and bridges we drive on. The production of cement releases the major greenhouse gas CO_2 both directly and indirectly. The heating of limestone releases CO_2 directly, while the burning of fossil fuels to heat the kiln indirectly results in CO_2 emissions. Hence to reduce this emission of CO_2 it is very much required to find an alternative for cement. Such an effective replacement is a geopolymer concrete. Geopolymer is a type of amorphous alumino-silicate cementitious material which can be synthesized by polycondensation reaction of geopolymeric precursor and alkali polysilicates known as geopolymerization process which produces a geopolymer concrete. This type of concrete can be produced by using any pozzolan, which are waste materials obtained from various processing units. In this study an attempt is made to produce geopolymer concrete by using a combination of Flyash and Saw dust ash. Saw dust is a waste material from the timber industry. It is produced as timber is sawn into planks at saw mills located in virtually all major towns in the country. The current practice with saw dust is as fuel for domestic cooking and for sand filling ditches in which it constitutes environmental nuisance. So this waste saw dust is burnt down in to finely powdered ash form and then used in the production of geopolymer concrete. Hence in this study different strength properties of geopolymer concrete mixture with Saw Dust Ash replaced in percentage to fly ash is experimented making workable, high strength and durable geopolymer concrete.

II. Literature Review

Saw Dust Ash (SDA) was replaced in varying percentage of about 5%,10%,15%,20% and 25% by weight of ordinary Portland cement. The results showed that Saw Dust Ash (SDA) is a good pozzolan with combined SiO2, Al2O3 and Fe2O3 of 73.07%. The slump and compacting factor decreased as the SDA content increased indicating that concrete becomes less workable as the SDA content increased. The compressive strength of concrete with SDA was lower at early stages but improves significantly up to 90 days[11]. The strength of geopolymer concrete based Waste Paper Sludge Ash (WPSA) incorporating with recycle concrete aggregate (RCA) increased by increasing the molarities of sodium hydroxide (NaOH)[1]. Fly ash based geopolymer concrete attained compressive strength higher than bottom ash based concrete. The low compressive strength is due to larger particle size in bottom ash. Larger particle size reduces the dissolution of bottom ash in activator solution and hence does not take part in the reaction[3]. Compressive strength of geopolymer concrete increases with increase in percentage of replacement of fly ash with GGBS[7].Curing temperature plays a vital role in geopolymer concrete. The compressive strength increases with increase in duration and temperature of oven curing. The rate of gain of strength is slow at 60°C compared to strength at 120°C. However, the compressive strength beyond 120°C is not significant[12]. With good quality control of the concreting process, 5% to 25% OPC replacement with SDA could be suitable for general reinforced concrete works, 25% to 40% for minor works in concrete, and 45% to 50% for plain concrete works[5]. 100% replacement of cement by ASTM class F fly ash and 100% replacement of sand by M-sand was analyzed and the results showed that Compressive strength results obtained for M-sand was nearly equal when compared to control concrete but Tensile strength of the river sand is high when compared to the M- Sand[2].

III. Sample Collection

The samples of saw dust was collected from Ambika Timber woods, Chennai .The samples were collected from a days waste of wood processed in the mill .The wood which is usually processed in this mill is Pine wood. Hence the saw dust collected from this mill contains pine wood dust as its major composition and the pine wood is 75 to 100 years old which show that it will have high silica content based on literatures. The samples were collected using gunny bags and then converted into ash by open burning in a metal container. The Burning process is shown in the Fig 1 and 2. The Burnt ash is then allowed to cool under environmental conditions for 12 hours and then collected using trowel into a safe container for material testing.

Fig .1.Initial Burning Stage

Fig .2. Final Burning stage

IV. Physical Composition of Saw Dust Ash

Saw dust which was obtained from timber milling factory is air-dried and then calcinated into ashes by open burning process as stated above. The ash was sieved and large particles retained on the 600μ m sieve were discarded while those passing the sieve were usedfor this work. No grinding or any special treatment to improve the ash quality and enhance its pozzolanicity was applied because the researchers wanted to utilize simple processes that can be easily replicated by local community dwellers. The resultant saw dust ash (SDA) was tested for bulk density, Specific Gravity and Fineness. The specific gravity of 2.36 and fineness modulus of 1.96 was obtained. The Properties obtained from the test is compared with the results from other Literatures. It was found that the Saw Dust Ash sample taken from the site has the same values of physical properties as those collected from the Literature studies. The Values were listed and compared in Table 1.

Table 1. Physical Properties of Saw Dust Ash from various literatures

Material Property	SDA Sample Taken	L. O. Ettu Et al [4] 2013	A. A. Raheem Et al [11] 2012	M. Mageswari Et al[10] 2008
Specific Gravity	2.36	2.05	2.19	2.5
Fineness modulus	1.96	1.89	-	1.78

The physical properties of Saw dust ash was then compared with other pozzolan materials which are generally used for making geopolymer concrete. The properties were almost similar to other pozzolan material which makes the SDA suitable for making geopolymer concrete.

V. Chemical Composition of Saw Dust Ash

The chemical composition of Saw Dust was tested in the laboratory to check whether the sample is a pozzolan material and can be used in the production of geopolymer concrete. The result obtained from the laboratory is shown in table 2. The composition of SiO_2+Al_2O_3+Fe_2O_3 is about 77.17%.Hence according to IS 3812:2003 this SDA sample can be used as a pozzolan material[8].

Table 2: Chemical composition of Saw dust Ash

Test Parameter	Result(%)
Alumina (Al_2O_3)	9.85
Silica (SiO_2)	62.87
Calcium (CaO)	10.35
Iron (Fe_2O_3)	4.45
Magnesium Oxide (MgO)	4.18
Sodium (Na_2O)	0.035
Potassium (K_2O)	1.71
Loss on ignition	5.85

VI. Physical Composition Of Aggregates

The various physical properties of both fine aggregates and coarse aggregates are found by manual testing procedures and they are listed one by one below:

A. Sieve Analysis

1).Coarse Aggregate

Sieve analysis is usually done for the aggregate for finding the particle size distribution in the aggregate. The particle size distribution will give us the grading of aggregates in a specified composition. Hence for this experimental work the sieve analysis is done by using 20mm sized saturated surface dry aggregates and the results were plotted in a semi log graph which is shown in Fig 3.

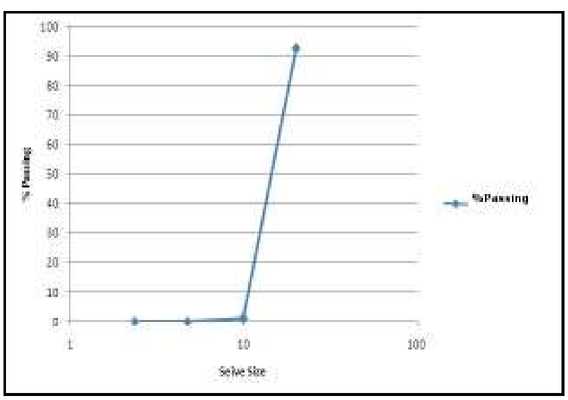

Fig.3.Semi log Graph of Coarse Aggregate

2).Fine Aggregate

The sieve analysis is done for fine aggregate also and results were plotted in a table format below. The results were then plotted in a semi log graph which is shown in the semi log graph below. The results show that the fine aggregate taken for testing comes under Zone II of IS 383:1970[9].

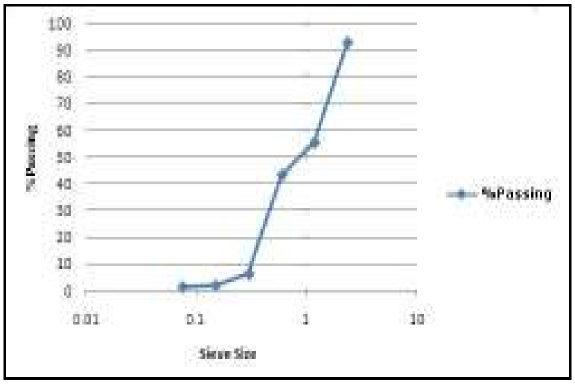

Fig.4. Semi log graph of Fine Aggregate

B.Specific Gravity

The Specific gravity values of coarse aggregate and fine aggregate are very important in determining the quantity required in the mix proportioning. Hence this test has to be done for both fine aggregate and coarse aggregate. The specific gravity of fine aggregate and coarse aggregate is done using laboratory tests and the results were tabulated in the table 3.

Table.3.Specific Gravity of Aggregates

S.No	Type of Aggregate	Specific Gravity
1	Fine Aggregate	2.54
2	Coarse Aggregate	2.68

VII. Mix Combinations

Following are the different Mix combinations which are going to be casted and tested in further study. The Fly Ash is going to be replaced with Saw Dust Ash in percentages of 0,5,10,15,20% by weight with flyash and the strengths are going to be determined. The mix combinations are listed in the table 4.

Table 4. Mix Combinations

Mix Values	Percentage of Binder in Geo-Polymer	
	Fly Ash	Saw Dust Ash
Mix 1	100	0
Mix 2	95	5
Mix 3	90	10
Mix 4	85	15
Mix 5	80	20

VIII. Mix Design:

There are no Indian standard specifications available for designing the mix of geopolymer concrete. Hence the Geopolymer mix is done by using literatures obtained.

In the design of geopolymer concrete mix, total aggregates (fine and coarse) taken as 77% of entire concrete mix by mass. This value is similar to that used in OPC concrete in which it will be in the range of 75 to 80% of the entire concrete mix by mass. Fine aggregate was taken as 35% of the total aggregates. From the available literature, it is observed that the average density of fly ash-based geopolymer concrete is similar to that of OPC concrete (2400 kg/m3). Knowing the density of concrete, the combined mass of alkaline liquid and fly ash can be arrived at. By assuming the ratios of alkaline liquid to fly ash as 0.4, mass of fly ash and mass of alkaline liquid was found out. To obtain mass of sodium hydroxide and sodium silicate solutions, the ratio of sodium silicate solution to sodium hydroxide solution was fixed as 2.5. In the present investigation, concentration of NaOH solution is taken as 8M.The proportioning for Binder: Fine Aggregate: Coarse

Aggregate is obtained as 1:1.76:3.28. So, the quantity of materials required for each mix combinations is tabulated below in table 5.

Table.5.Mix Proportioning

S.NO	Materials	MIX 1 Kg/m^3	MIX 2 Kg/m^3	MIX3 Kg/m^3	MIX 4 Kg/m^3	MIX 5 Kg/m^3
1	Fly Ash	368	349.6	331.2	312.8	294.4
2	Saw Dust Ash	0	18.4	36.8	55.2	73.6
3	Fine aggregate	647	647	647	647	647
4	Coarse aggregate	1201	1201	1201	1201	1201
5	Sodium Hydroxide (NaOH)	52.57	52.57	52.57	52.57	52.57
6	Sodium Silicate (Na_2Si0_3)	131.43	131.43	131.43	131.43	131.43
7	Additional Water Required	36.8	36.8	36.8	36.8	36.8

IX. Casting of Cubes:

A. Workability:

Workability is the ability of a fresh concrete mix to fill the mould properly with required vibration and without reducing the concrete's quality. Workability depends on water content, aggregate (shape and size distribution), cementitious content and age (level of hydration) and can be modified by adding chemical admixtures, like superplasticizer.

Workability can be measured by the concrete slump test, a simplistic measure of the plasticity of a fresh batch of concrete. Slump is normally measured by filling an slump cone with a sample from a fresh batch of concrete. The Geopolymer mix which is mixed based on the above proportion is filled in the slump cone upto the top level and then the cone is carefully lifted off, the enclosed material slumps a certain amount due to gravity. So the slump value is found for two cases. First the slump is measured before adding additional water and then the next one would be after adding additional water. It was found that the workability increased a large margin after adding that additional amount of water.

Table.6. Workability of concrete

S.No	Slump Value of Geopolymer Concrete Mix	
	Before Adding Additional Water	After Adding Additional Water
1	25	107

B. Casting:

Trial cubes were casted using mould size of 100x100x100mm at the beginning for initial testing. The cubes were cured at normal temperatures without using oven for curing at higher temperatures. It was found that the cubes haven't set to any amount until 3 days from the day of casting because of not curing at higher temperatures.

Fig.5. 100mm cubes with Geopolymer concrete

Hence a concrete cube of 150x150x150 mm has been cast again and then they are placed in oven for heat curing at a temperature of 60^{o}C. The cubes were casted using conventional method i.e. by manually using trowel and manual mixing. The mould was first oiled and then the mixed geopolymer mix was poured into it and then placed in oven curing for drying process.

Fig.6.150 mm cubes casted for testing

After curing, the strength of the cubes was tested at 7 days and 28 days. The compressive strengths of the cubes were determined by using compressive testing machine. The testing image is shown in figure 7. The various test results obtained are listed in the table.7.

Fig.7.Compressive testing of cube specimen

Table.7.Compressive Strength at 7 days for various mixes

S.NO	MIX Combinations	Compressive Strength At	
		7 Days N/mm^2	28 Days N/Mm^2
1	MIX 1	26.88	35.51
2	MIX 2	26.84	35.6
3	MIX 3	24.44	33.29
4	MIX 4	23.60	32.4
5	MIX 5	22.57	29.11

It was found the value of compressive strength for 5% replacement of saw dust ash is almost similar to that of the compressive strength obtained with the control mix i.e. for mix 1.After that it was found that further replacement of sawdust ash reduces the compressive strength a little by little. Hence with 7 day strength obtained it was found that replacement of fly ash by saw dust ash up to 5% provides satisfactory results. The variation of strength is indicated in the form of a graph in figure.8.

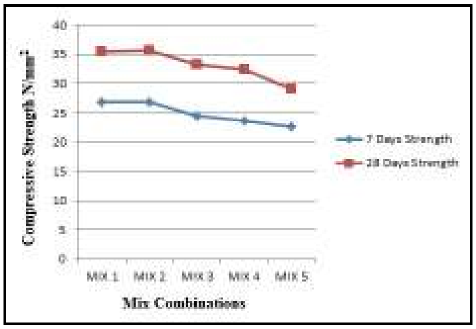

Fig.8. Variation of 7 day strength and 28 days strength with different mix combinations

A cylinder of size 150mm diameter and 300mm height is being casted for further strength study of the mixes in a better manner. The concrete cylinders are placed in the compression testing machine. Load is applied to the specimen uniformly, until the specimen fails. Loaded at failure is noted. This load is the ultimate tensile load. The concrete cylinder is tested according to IS: 5816- 1976, procedure for split tensile test. The results obtained are tabulated in table.8.

Table.8. Split Tensile Strength of Geopolymer

S.No	Mix Combinations	Split Tensile Strength At 7 Days N/mm^2	Split Tensile Strength At 28 Days N/mm^2
1	Mix 1	2.61	4.62
2	Mix 2	2.65	4.59
3	Mix 3	2.55	4.53
4	Mix 4	2.50	4.49
5	Mix 5	2.44	4.45

The flexural strength of the beam is found as per the procedure shown above by casting beams of size 100mm x 100mm x 500mm.The beams are tested after its maturity on 7 days and 28days. The various results obtained of flexural strength obtained in the beam after 7 days and 28 days are shown below in Table 9.

Table.9.Flexural Strength of Geopolymer

S.No	Mix Combinations	Flexural Strength At 7 Days N/mm^2	Flexural Strength At 28 Days N/mm^2
1	Mix 1	2.80	4.79
2	Mix 2	2.78	4.81
3	Mix 3	2.75	4.69
4	Mix 4	2.71	4.61
5	Mix 5	2.65	4.55

X. Results and Discussions

Saw Dust ash obtained from Timber Industries was used as an alternative material along with Flyash in the production of geopolymer concrete. From the results obtained from various experimental works carried out the following conclusions were drawn:

- Curing temperature is very much important in the activation process of geopolymer concrete. Hence curing at 60^oC made the activation process possible.
- Geopolymer concrete shows higher compressive strengths at Na_2SiO_3: NaOH ratio of 2.5.

- Workability of Geopolymer concrete is very low when nominal mix is used. Hence any super plasticizer or some additional water has to be added to make the concrete workable.
- Compressive strength of Geopolymer decreases with increase in content of Saw dust ash. Nominal strength which is almost same as that of the control cube is obtained up to a replacement level of 5% with SDA in fly ash. Hence Flyash can be replaced by Saw dust ash up to a replacement level of 5% to produce Geopolymer concrete.
- Similar Results were obtained in case of tensile strength as well as in flexural strength. Higher strength is obtained till 5% replacement of fly ash by SDA. Increase in proportion of SDA more than 5% decreases the strength.

XI. References

1. Anuar K.A, Ridzuan A.R.M., Ismail S.(2011) ,Strength Characteristic of Geopolymer Concrete, International Journal of Civil & Environmental Engineering., Vol. 11(1), pp. 59-62.
2. Anuradha.R, Sreevidya.V, Venkatasubramani.R and B.V.Rangan (2012), Modified Guidelines for Geopolymer concrete mix design using Indian Standards, Asian Journal of civil Engineering, Vol.13 (3), pp. 353-364.
3. Bennet Jose Mathew, Sudhakar M, Natarajan C, Strength, Economic and Sustainability Characteristics of Coal Ash – GGBS Based Geopolymer Concrete, International Journal Of Computational Engineering Research, Vol.3 (1) ,pp. 207-212.
4. Ettu.L.O, Ibearugbulem.O.M, Anya.U.C, C. T. G. Awodiji, F. C.Njoku (2013), Strength of Binary Blended Cement Composites Containing Saw Dust Ash, The International Journal Of Engineering And Science (IJES), Vol. 2(4), pp. 51-56.
5. Ettu.L.O, Mbajiorgu.M.S.W and Nwachukwu.K.C, Variation Of Opc-Rice Husk Ash Composites Strength Under Prolonged Curing, International Journal of Engineering Research & Technology, Vol. 2(7) , pp. 2276-2283.
6. Ettu.L.O, Anya.U.C, Nwachukwu.K.C, Arimanwa.J.I and Opara.H.E, “Variation of Opc-Rice Husk Ash-Saw Dust Ash Composites Strength with Water-Cement Ratio”, International Journal of Engineering Research and Development, Vol. 8(3), pp . 26-30.
7. Ganapati Naidu, Prasad.A.S.S.N, Adiseshu.S and Satyanarayana.P.V.V (2012), A Study on Strength Properties of Geopolymer Concrete with addition of G.G.B.S, International Journal of Engineering Research and Development , Vol.2(4), pp. 19-28.
8. IS 3812:1981, Indian standard specification for fly ash for use as pozzolana and admixture.
9. IS 383:1970, Specification for Coarse And Fine Aggregates from Natural Sources For Concrete.
10. Mageswari.M and Vidivelli.B (2009), The Use of Saw Dust Ash as Fine Aggregate replacement in Concrete, India, Journal of Environmental Research and Development, Vol. 3, Issue 3, pp. 720-726.
11. Raheem.A.A, Olasunkanmi.B.S, Folorunso.C.S (2012), Saw Dust Ash as Partial Replacement for Cement in Concrete, organization technology and management in construction, International Journal Vol. 4, Issue 1 pp. 474-480.
12. Satpute Manesh B., Wakchaure Madhukar R., Patankar Subhash V(2012),Effect of Duration and Temperature of Curing on Compressive Strength of Geopolymer Concrete, International Journal of Engineering and Innovative Technology (IJEIT),Vol.1(5), pp. 152-155.

*****