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Experimental Investigation on Fly Ash Based Geopolymer Concrete with Partial Replacement of Fly Ash by Paper Sludge Ash

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ABSTRACT

Portland cement is the widely used binder material for concrete in variety of constructions. As the demand for concrete as a construction material increase, the demand for Portland cement also gets increases. The production of cement involves emission of carbon dioxide (CO2), which produces greenhouse effect. It is estimated that the production of cement will increase from about 1.5 billion tons in 1995 to 2.20 billion tons by 2010. Among the greenhouse gases, CO2 contributes about 65% global warming. The cement industry is held responsible for some of the CO2 emissions, because the production of one ton of Portland cement emits approximately one ton of CO2 into the atmosphere. In recent years in addition to the development of the replacement materials in cement concrete for the cement development of alternative binders also came into emerge.Among the different alternative binder concrete such as bacterial concrete, nano concrete etc., Geopolymer concrete was significance in respect of its properties.

Geopolymer is an inorganic alumino-silicate polymer synthesized from predominantly silicon (Si) and aluminum (Al) materials of geological origin or by-product materials such as fly ash. The process involves a chemical reaction under highly alkaline conditions on Si-Al minerals, yielding polymeric Si-O-Al-O bonds in amorphous form. The geopolymer is used as the binder, instead of cement paste that paste binds the loose coarse aggregates, fine aggregates and other un-reacted materials together to form the geopolymer concrete.

The present thesis work aims at the study of fly ash based geopolymer concrete with paper sludge ash as partial replacement of fly ash under various curing conditions such as Hot air Oven curing, Sun light curing and Ambient curing.

Literature studies have been carried out about the geopolymer concrete, paper sludge ash in cement concrete etc. Further the properties of raw material for geopolymer concrete are also studied. And bond strength find out for varying percentage fly ash replacement by paper sludge ash for 0%,5%,10%,15% and 20% in geopolymer concrete.

In this study Flexural behavior of geopolymer concrete beams, flexural strength test, Load carrying capacity, ductility factor, crack pattern, beam deflection and moment curvature etc., for the geopolymer concrete produced from the Fly Ash and Paper Sludge Ash with Catalytic liquid system and aggregates under various curing conditions such as Hot air Oven curing, Sun light curing and Ambient curing.

1 INTRODUCTION

1.1 GENERAL

Climate change due to global warming has become a major concern. Global warming is caused by the emission of greenhouse gases, such as carbon dioxide (CO_2), to the atmosphere by human activities. Among the multiple greenhouse gases, CO_2 contributes to approximately 65% of global warming. The cement industry is held responsible for some amount of CO_2; the production of one ton of cement is responsible for the emission of approximately one ton of CO_2 to the atmosphere.

Recently another form of cementitious material, using silicon and aluminium activated in a highly alkali solution, has been developed (1999). Geopolymer is an inorganic alumino-silicate compound, synthesized from by-product materials such as fly ash, rice husk ash, paper sludge ash, etc., that are rich in silicon and aluminium. The Geopolymer concrete is produced by totally replacing the ordinary Portland cement concrete. Therefore the use of Geopolymer concrete technology not only substantially reduces the CO_2 emissions by the cement industries, but also utilizes the waste materials such as fly ash and paper sludge ash.

Geopolymers are inorganic materials of cementitious nature derived from the alkaline activation of alumino-silicate materials which can be either readily available natural material such as kaolinitic clay or industrial by-products such as fly as and paper sludge ash. The term Geopolymer was introduced by Joseph Davidovits of France to represent the mineral inorganic polymer with better resistance of fire, where silicon element plays a major role similar to the Carbon of the organic polymers.

Geopolymer based materials can be considered as environmentally friendly since they need moderate quantity of energy to produce. However, their performance as a construction material has to be comparable with that of Portland cement in order to accept them in practical applications. At present Geopolymerization can lead to possible solutions for utilization of many industrial by-products and the advantages of Geopolymer concrete could be exploited by construction industry in applications such as pre-fabrication/precise systems, concrete, paving block, Railway sleepers and building blocks.

1.2 GEOPOLYMER

The term "Geopolymer" was coined by Davidovits in 1978. This inorganic alumino silicate polymer is synthesized from predominantly silicon and alumunium material of geological origin or by-product materials such as, fly ash. Chemical compositions of Geopolymer materials are similar to zeolite.

Davidovits (1993) introduced the term "Geopolymers" to the chemical world and in so during a new field of research and technology was created. He explained that "geosynthesis" is the science of manufacturing artificial rock at a temperature below 100^0C in order to obtain natural characteristics (hardness, Longevity and heat stability). Geopolymers were thus viewed as mineral polymers resulting from geochemistry or geosynthesis.

The choice of the source materials for making Geopolymers depends on factors such as availability, cost, type of application, and specific demands of the end users. The alkaline liquids are obtained from soluble alkali metals that are usually sodium or potassium based. The most common alkaline liquid used in geopolymerization is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate.

Geopolymer is a type of amorphous alumino-silicate material. Geopolymer can be synthesized by polycondensation of geopolymer precursor, and alkali polysilicates.Geopolymer is used as binder, instead of cement paste, to produce concrete binds the loose coarse and fine aggregates and other un-reacted materials together to form geopolymer concrete. Geopolymers are inorganic materials of cementitious nature. Derived from the alkaline activation of alumino-silicate materials which can be either readily available natural material such as kaolinitic clay or industrial by-products such as FA and PSA. Low calcium dry fly ash (class F) obtained from local power station was used as source material.

For the alkaline liquid activator, a combination of sodium hydroxide solution and sodium silicate solution was used .The sodium hydroxide solution was prepared by dissolving the sodium hydroxide pellets in distilled water. All the liquids are mixed together before one day, adding in the aggregates. The aggregates in saturated dry condition and the dry fly ash were mixed together. At the end of this mixing, the alkaline solution was added to the aggregates, and the mixing is continued for specified period of time. It is glossy in nature.

1.3. CONSTITUENTS OF GEOPOLYMER CONCRETE

- Fly ash
- Paper sludge ash
- Fine aggregates
- Coarse aggregates
- Sodium hydroxide (NaOH) by means of pellets
- Sodium silicate in liquid form

2 MATERIALS

2.1 FLY ASH

Fly ash is defined in Cement and Concrete terminology as "the finely divided residue resulting from the combustion of ground or powdered coal, which is transported from the firebox through the boiler by flue gases". Fly ash is a by-product of coal-fired electric generating plants. Fly ash consists of earthy mineral which includes silicon, aluminium, iron, calcium, magnesium and traces of titanium and organic matter such as carbon.

FIG 2**.1 FLY ASH**

2.1.1 OCCURENCE

Fly ash is a byproduct material coal based thermal power plants and for every 3000 MW of power generated, about 500 kg of fly ash is produced. Fly ash is comprised of the non-combustible mineral portion of coal consumed in a coal fueled power plant. Fly ash particles are glassy, spherical shaped “ball bearings” typically finer than cement particles that collected from the combustion air-stream exiting the power plant.

Two classifications of fly ash are produced, according to the type of coal used. Anthracite and bituminous coal produces fly ash classified as Class F. Class C fly ash is produced by burning lignite or sub-bitiminous coal

2.1.2 UTILIZATION IN INDIA

Fly ash is produced on large scale in India and its utilization level is only about 40%. Its large scale availability in countries like India is creating disposal problems and hence there is a need for development of ecofriendly applications of FA. The disposal of coal combustion by-product wastes has been a current issue during the past few decades. Applications in many fields of Civil Engineering, Automotive and Aerospace Engineering, Non ferrous foundries and Metallurgy, Plastic Industries waste management, art and Retrofit of buildings

In the present investigation work, the fly ash used is obtained from **Mettur Thermal Power Station (MTPS), Mettur Dam, Salem**

2.1.3 PHYSICAL PROPERTIES OF FLY ASH

S.NO	Types of Test	Fly Ash – Class F
1	Specific gravity	1.90
2	Consistency	34%
3	Fineness	7%
4	Water content	NIL

Table.5.1 Physical properties of Fly ash

2.1.4 CHEMICAL PROPERTIES FLY ASH

1. Silicon dioxide (SiO_2) - 60.54%
2. Alumina (Al_2O_3) - 23.87%
3. Iron Oxide (Fe_2O_3) - 9.64%
4. Magnesium Oxide (MgO) - 1.52%
5. Calcium Oxide - 1.07%

2.2 PAPER SLUDGE ASH

Paper mill sludge is often incinerated for heat recovering and also for an important volume reduction. In Italy about $6x10^{5}$ tons of paper sludge is yearly produced giving 60kg of paper ash per ton. The ash coming from burning of paper mill sludge from primary mechanical separation process, fired as single fuel, was studied in order to evaluate its use as cementitious material in concrete manufacturing. On the other hand, due to its high fineness and consequently high water absorption, it requires a higher dosage of water, so that the use of paper ash should not be higher than 10% by weight of cement.

FIG 2**.2 PAPER SLUDGE ASH**

2.2.1 OCCURENCE

Paper sludge ash is a by-product formed by the incineration of paper sludge. The waste by-product (wet paper sludge) received from different kind of paper manufacturing industries are allowed for drying. The wet paper sludge can be converted in to pellet form and then it is dried. By incinerating the dried paper sludge at about 500-800^{0}C, besides getting energy huge quantity of ash produced.

In this work wet paper sludge ash was collected from Pallipalayam SPB paper mill.

2.2.2 UTILIZATION

1. Land filling & land spreading
2. Compositing
3. Brick, light aggregates and cement production
4. Energy production in brick and paper industry
5. Sorbent material production
6. Cleaning of oil spills from water surfaces

2.2.3 PHYSICAL PROPERTIES OF PAPER SLUDGE ASH

Table 5.3 Physical properties of Paper Sludge Ash

S.NO	**Types of Test**	**Paper Sludge Ash**
1	Specific gravity	2.29
2	Consistency	38%
3	Fineness	1.1%
4	Water content	NIL

2.2.4 CHEMICAL PROPERTIES OF PAPER SLUDGE ASH

Chemical Properties of Paper Sludge Ash

S.No	Components	IS 3812 2003 specifications (%)	Paper sludge ash (SPB) %
1	SiO_2+Al_2O_3+Fe_2O_3	70 Min	87.43
2	SiO_2 (Alone)	35 Min	71.17
3	MgO	5 Max	3.84
4	LOI	12 Max	-
5	CaO	-	7.04

2.3 FINE AGGREGATE (RIVER SAND)

In the present investigation Normal River sand was used as a fine aggregate, which is available in Salem, extracted from Cauvery River near Musiri. The fine aggregate was screened at site to remove deleterious materials and tested as per procedure given in IS 2386 1963. The results of sieve analysis of typical fine aggregates are given in table 5.8. The fineness modulus of sand 3.48.

FIG 2.3 FINE AGGREGATE

2.3.1 SIEVE ANALYSIS OF TYPICAL FINE AGGREGATE

Sieve no	Wt. retained gms	Cumulative wt. retained gms	% cumulative wt. retained gms	% cumulative wt. passing gms	Permissible limits IS 383-1970
10mm	-	-	-	100	100
4.75mm	-	-	-	100	90-100
2.36mm	14	14	1.4	98.6	75-100
1.18mm	104	118	11.8	88.2	55-90
600 mic	364	482	48.2	51.8	35-59
300 mic	397	879	87.9	12.1	8-30
150 mic	113	992	99.2	0.8	0-10
75 mic	8	1000	100	-	-

Sieve analysis of typical fine aggregate in Zone II

2.3.2 DETERMINATION OF SPECIFIC GRAVITY OF FINE AGGREGATE

Empty weight of pycnometer (m1) = 633.0gms

Empty weight of pycnometer +Sand (m2) = 1049.0 gms

Empty weight of pycnometer +Sand +Water (m3) = 1636.0 gms

Empty weight of pycnometer +Water (m4) = 1374.0 gms

Specific gravity of sand = $\frac{m3-m1}{(m2-m1)-(m3-m4)}$ **= 2.70**

2.4 COARSE AGGREGATE

Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. One of the most important factors for reducing workable concrete is good gradation of aggregates. Good grading implies that a sample fractions of aggregates in required proportion such that the sample contains minimum voids. Samples of the well graded aggregate containing minimum voids require minimum paste to fill up the voids in the aggregates. Minimum paste will mean less quantity of binding material and less water, which will further mean increased economy, higher strength, lower shrinkage and greater durability.

In the present investigation, crushed hard blue granite aggregates were obtained from the locally available and approved quarries were used.

FIG 2.4 **COARSE AGGREGATE**

2.4.1 SIEVE ANALYSIS TEST FOR COARSE AGGREGATE

2.4.1.1 Sieve Analysis of Typical normal Coarse Aggregate sample (20mm)

Sieve no	Weight retained gms	Cumulative wt. retained gms	% cumulative wt. retained gms	%cumulative wt. passing gms	Permissible limits IS 383-1970
40 mm	-	-	-	100	100
20 mm	742	742	14.84	85.16	85-100
16 mm	2194	2936	58.72	41.28	-
12.5 mm	1150	4086	81.72	18.28	-
10 mm	525	4611	92.22	7.78	0-30
4.75 mm	389	5000	100	-	0-5

Sieve Analysis of Typical normal Coarse Aggregate sample (20mm)

2.4.1.2 Sieve Analysis of Typical normal Coarse Aggregate sample (12.5mm)

Sieve no	Weight retained gms	Cumulative wt. retained gms	% cumulative wt. retained gms	%cumulative wt. passing gms	Permissible limits IS 383-1970
20 mm	-	-	-	-	-
16 mm	-	-	-	100	100
12.5 mm	741	741	14.82	85.18	85-100
10 mm	2433	3174	63.48	36.52	0-45
4.75 mm	1826	5000	100	-	0-10

Sieve Analysis of Typical normal Coarse Aggregate sample (12.5mm)

For our experimental work the coarse aggregate should be 60% of 20mm size and 40% of 12.5mm size are used, so that the aggregates are well graded and give better workability, minimum paste content & maximum strength obtained. The physical properties of specific gravity, soundness, flakeness index, elongation index, surface texture, water absorption, impact and hardness tests are carried out to the required limit as per standards to obtain the maximum results.

2.4.2 DETERMINATION OF SPECIFIC GRAVITY OF COARSE AGGREGATE

1. Determination of specific gravity coarse aggregate (20mm)

Empty weight of pycnometer (m1) = 444.0gms

Empty weight of pycnometer +Aggregate (m2) = 891.0 gms

Empty weight of pycnometer +Aggregate +Water (m3) = 1481.0 gms

Empty weight of pycnometer +Water (m4) =1192.0 gms

$$\textbf{Specific gravity of 20mm Aggregate} = \frac{m3-m1}{(m2-m1)-(m3-m4)} = 2.829$$

2. Determination of specific gravity coarse aggregate (12mm)

Empty weight of pycnometer (m1) = 374.0gms

Empty weight of pycnometer +Aggregate (m2) = 767.0 gms

Empty weight of pycnometer +Aggregate +Water (m3) = 1296.0 gms

Empty weight of pycnometer +Water (m4) =1046.0 gms

$$\textbf{Specific gravity of 12mm Aggregate} = \frac{m3-m1}{(m2-m1)-(m3-m4)} = 2.748$$

2.5 ALKALINE LIQUIDS

Sodium silicate (Grade A53) used in a solution from mixed 65.50% of water, 26.50% of SiO_2 and 12% of Na_2O.Sodium hydroxide used was in the form of pellets. Concentration of solution was 12M and in order to take 1 kg of solution, 29.40% of pellets were added to water.

FIG 2.5 ALKALINE

2.5.1 CHARACTERISTICS OF SODIUM SILICATE

Colour - Colourless or white solution/solid form

Solubility in water - 22.2/100ml (25 C)

Specific heat capacity - 111.8 J/mol/K

Density -2.61 g /cm3

2.5.2 CHARACTERISTICS OF SODIUM HYDROXIDE

Colour - whitish solid in pellets

Solubility in water -111g/100ml (20 C)

Specific heat capacity - 59.66 J/mol/K

Density -2.13 g /cm3

2.6 STEEL REINFORCEMENT DETAILES

High yield strength deformed bar Fe 500

3 MIX PROPORTIONS

Fly ash	Fine aggregate	Coarse aggregate	Alkaline liquid
438 kg/m^3	857 kg/m^3	1207 kg/m^3	197 kg/m^3
1	**1.96**	**2.76**	**0.45**

4EXPERIMENTAL INVESTIGATION

4.0 GENERAL

The main objective of the present experimental investigation is to obtain specific experimental data, which helps to understand the fly ash based geopolymer concrete with paper sludge ash as partial replacement of fly ash and its strength characteristics.

In the present experimental investigation, studies have been carried out on the behaviour of hardened properties i.e., Bond strength test , flexural strength test, Load carrying capacity, ductility factor, crack pattern, beam deflection and moment curvature are determined by the conducting suitable laboratory tests on concrete in hardened stage.

4.1 BOND STRENGTH TEST (PULL OUT TEST)

- Bond strength between paste and steel reinforcement is of considerable importance.
- A perfect bond, existing between concrete and steel reinforcement is one of the fundamental assumptions of reinforced concrete.
- Bond strength arises primarily from the friction and adhesion between concrete and steel.
- The roughness of the steel surface is also one of the factors affecting bond strength.
- The bond strength of concrete is a function of compressive strength and is approximately proportional to the compressive strength

Bond strength = $P_{max}/\pi LD$

P_{max} - Max. Load at failure

L - Length of bar inserted

D - Dia. of bar

FIG 4.1 BOND STRENGTH ON CYLINDERS

4.2 FLEXURAL STRENGTH TEST

To determine the flexural strength of geopolymer concrete and control cement concrete beam moulds of size 2000mmx125mmx250mm were used. The beam moulds were cleaned throughly using a waste cloth and properly oiled along its face. The concrete material was mixed in a mixture machine and concrete as then filled in mould and then compacted in using a table vibrator. After curing, all the specimens were white washed in order to facilitate marking of cracks. The specimens were tested for flexural strength of 28 days.

The beams are tested under symmetrical two point loading on over hanging span of 300mm and 1700mm. The beam is placed on one roller and one hinged supports, resting on iron blocks, placed on the wing table of the loading frame. Before resting the beam on iron blocks, the beam was centered by using a plumb bob so that its center lies exactly under the center of the loading head. The beam was simply supported over a span of 1850 mm, which is considered as the effective span. The beam was supported on the iron blocks by a hinged plate at one end and roller plate at the other end. The load is from the fixed cross head of the machine as two point loading, on the one roller, one hinged placed one third from the support apart, by a loading beam of sufficient stiffness. The two point load applied in applicable to the specimen at slow rate till the specimen fails. Flexural cracks were marked on the beam at every load interval.

Flexural strength of beam can be calculated by following formula,

$$\textbf{Flexural strength} = P*l/ b*d^2$$

Where,

P = Maximum load in kg applied to the specimen

l = length of the specimen in mm

d = depth measured in cm of the specimen at the point of failure

b = measured width of the specimen in mm

TESTING SETUP:

BEAM TESTING:

4.3 DUCTILITY FACTOR:

Ductility factor can be calculated by using the formula,

$$\textbf{Ductility factor} = x_1/x_0$$

Where,

x_1 = ultimate load deflection

x_0 = yield load deflection

4.4 MOMENT CURVATURE:

Moment-curvature relations can be calculated from three criteria by computing the curvature (rotation per unit length) using deflection at midspan, combination of deflection at midspan and load points and linear strain distribution across a section. By plotting a graph between radius of curvature along X-axis, moment along Y-axis,

$$M = \frac{PL}{6}$$

P – Load in KN

L – Span of the beam in m

M – Moment in KNM

$$Ø = \frac{36\ \delta 2 + L\ 2}{72\ \delta}$$

δ – Deflection at mid span

Ø – Radius of Curvature

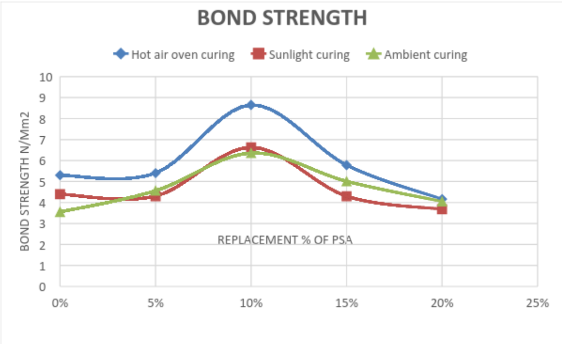
5 EXPERIMENTAL RESULTS AND DSCUSSION

5.1TEST RESULTS ON BOND STRENGTH OF GPC SPECIMENS

The bond test were conducted on cylindrical specimens of size 100mm dia x 200mm height made by using fly ash and paper sludge ash and the test results were tabulated below in Table 7.1

TABLE 5.1 BOND STRENGTH ON CONCRETE CYLINDERS

TESTING SPECIMENS	HOT AIR OVEN CURING					SUNLIGHT CURING					AMBIENT CURING				
	0%	5%	10%	15%	20%	0%	5%	10%	15%	20%	0%	5%	10%	15%	20%
1	5.35	5.50	7.80	6.32	4.77	4.15	4.25	7.69	4.51	3.55	3.40	4.50	6.36	5.14	4.56
2	5.25	5.30	9.50	5.25	3.55	4.65	4.35	5.57	4.08	3.82	3.70	4.62	6.36	4.88	3.55
AVERAGE	5.30	5.40	8.65	5.78	4.16	4.40	4.30	6.63	4.30	3.68	3.55	4.56	6.36	5.01	4.05



Bond strength test results were conducted on cylindrical specimens of size 100mm dia x 200mm height. From the graphs we can see that the increase in percentage of paper sludge ash 10% increases the bond strength and then it will be decreased. The maximum value of bond strength is 8.65 N/mm^2 in hot air oven curing.

5.2 FLEXURAL STRENGTH OF BEAMS TEST RESULTS

The flexural strength test were conducted on beam specimens of size 2000mm x 125mm x 250mm made by using fly ash and paper sludge ash and optimize percentage replacement of fly ash by paper sludge ash 10% is taken for flexural study. The flexural tests were conducted and deflection for the applied load was recorded for the curing age of 28 days and the test results were tabulated below in Table 7.2

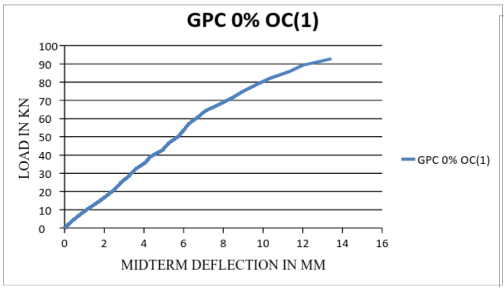
TABLE5.2 **FLEXURAL STRENGTH OF BEAMS TEST RESULTS**

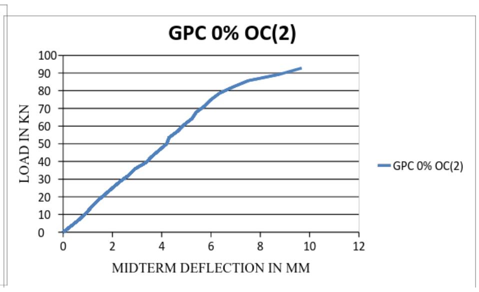
Sl.No	Name of specimen	First crack load (KN)	Mid span deflection (mm)	Service load (KN)	Yield load (KN)	Ultimate load (KN)	Flexural strength (N/mm^2)
1	GPC-OC-0%-(1)	17.85	12.54	61.88	88.00	92.82	24.97
2	GPC - OC-0%(2)	17.85	10.50	61.88	85.00	92.82	24.97
3	GPC -SLC-0%- (1)	14.28	13.32	42.84	58.00	64.26	17.26
4	GPC-SLC-0%(2)	10.71	12.33	45.22	62.00	67.83	18.22
5	GPC-AC-0%(1)	7.14	10.84	33.32	45.00	49.98	13.44
6	GPC-AC-0%(2)	7.14	22.99	35.70	50.00	53.55	14.40
7	GPC-OC-10%-(1)	28.56	15.20	58.00	67.00	87.00	23.40
8	GPC-OC-10%-(2)	24.99	14.20	56.00	60.00	84.00	22.59
9	GPC-SLC-10%-(1)	21.42	13.62	57.12	82.00	85.68	23.04
10	GPC-SLC-10%-(2)	21.42	12.69	54.74	77.00	82.11	22.08
11	GPC-AC-10%-(1)	24.99	14.33	54.74	70.00	82.11	22.08
12	GPC-AC-10%-(2)	21.42	14.30	52.36	67.00	78.54	21.13

TABLE: 5.3 COMPARISON OF ULTIMATE LOADS OVER OVEN CURING BEAM 0%

S.NO	SPECIMEN	ULTIMATE LOAD(AVG)	REMARKS
1	GPC-OC-0%	92.82	-
2	GPC-OC-10%	85.50	7.88 % < GPC-OC-0%
3	GPC-SLC-0%	66.04	28.84 % < GPC-OC-0%
4	GPC-SLC-10%	83.90	9.61 % < GPC-OC-0%
5	GPC-AC-0%	51.76	44.23 % < GPC-OC-0%
6	GPC-AC-10%	80.32	13.46% < GPC-OC-0%

FLEXURAL STRENGTH OF BEAMS TEST RESULTS (GRAPH)





6 CONCLUSION

The significant conclusions drawn from the study are given below.

1. As a new material to the Geopolymer concrete the paper sludge ash can be used as a replacement material to flyash and cement.
2. Bond strength test results were conducted on cylindrical specimens of size 100mm dia x 200mm height. From the Results we can see that the increase in percentage of paper sludge ash 10% increases the bond strength and then it will be decreased. The maximum value of bond strength is 8.65 N/mm^2 in hot air oven curing.
3. From the flexural behavior of GPC beam, among three different curing condition viz. Hot air oven curing, Sunlight curing and ambient curing, the 100% FA based GPC produce higher flexural strength of 24.97 N/mm2 under hot air oven curing compare to other
4. On adding 10% PSA into the FA based GPC beam, the flexural strength is more or less same among three different curing condition in the following order HAOC >SLC >AC
5. By using PSA into FA based GPC the concrete can be cured even under ambient temperature which produce flexural strength of 22.08 N/mm2 (than greater than ambient cured FA based GPC beam).
6. From the structural behavior of beam study of geopolymer concrete with PSA (10%), it was concluded that the FA based geopolymer concrete with PSA can be used for manufacturing structural member. Successful Commercial productions of precast geopolymer units such as Box culverts, sewer pipe lines were available.
7. The failure pattern of all the beam specimens was found to be similar. At early load stages, flexural cracks appeared in the center portion of the beam, and gradually spread towards the supports. As the load increased existing cracks propagated and new cracks developed along the span. The failure occurred by the crushing of concrete in the compression zone, notably beneath and adjacent to the loading plates. Concrete spalling at the compression zone was observed after the ultimate load.
8. From the bond strength, flexural strength behavior of FA based GPC and PSA&FA based GPC member, finally it is recommended to use the sunlight temperature and ambient temperature cured PSA&FA based GPC members on considering economic factors.
9. Even though the cost of fly ash, paper sludge ash based geopolymer conrete production in the lab is high, the large scale industrial commercial products will reduce the cost considerably.

7 OBJECTIVE AND SCOPE

7.1 OBJECTIVE OF THE STUDY

The main objective of this investigation is to study the Flexural behavior of geopolymer concrete beams, flexural strength test, Load carrying capacity, ductility factor, crack pattern , beam deflection and moment curvature etc., the fly ash based geopolymer concretes beams made by using paper sludge ash as partial replacement of fly ash with the usage of suitable alkali activators along with coarse and fine aggregates.

The studies are to be made under three different curing conditions of Geopolymer concrete various types of curing such as Hot air Oven curing, Sunlight curing and Ambient curing.

7.2 SCOPE OF THE WORK

The chemical composition of paper sludge ash is similar to that of low calcium fly ash. Hence the paper sludge ash can be used as a partial replacement to the fly ash in Geopolymer concrete.

Based on the partial replacement studies on Geopolymer concrete the Experimental studies can be continued by using paper sludge ash as raw binding material for the new type of Geopolymer concrete.

REFERENCES

i. Concrete Technology,Theory and Practice M.S.Shetty

ii. B. Vijaya Rangan, Djwantoro Hardjito, Steenie E. Wallah, and Dody M.J. Sumajouw Faculty of Engineering and Computing, Curtin University of Technology, Australia.

iii. P. Nath, P. K. Sarker. Department of Civil Engineering, Curtin University, Kent Street, Bentley, Australia.

iv. Geopolymer concrete: a concrete of Next decade Raijiwala D.B. Patil H. S.

v. Fly Ash-Based Geopolymer Mortar Incorporating Bottom AshDjwantoro HARDJITO.Dept. of Civil Engineering. Petra Christian University

vi. Hardjito D. (2005). Studies of fly ash-based geopolymer concrete. PhD Thesis, Curtin university of Technology, Perth, Australia.

vii. Vijai K., Kumutha R. and Vishnuram B. G. (2010). Effect of types of curing on strength of geopolymer concrete. International Journal of the Physical Sciences, 5(9), 1419-1423.

viii. Davidovits J. (2008). Geopolymer Chemistry and Application. 2nd edn, Institut Géopolymère, Saint-Quentin, France.

ix. Wallah S. E. and Rangan B. V. (2006). Low-calcium fly ash-based geopolymer concrete: long-term properties. Research Report GC 2, Faculty of Engineering, Curtin University of Technology, Perth, Australia.

x. Wu H. C. and Sun P. (2010). Effect of mixture compositions on workability and strength of fly ash-based inorganic polymer mortar, ACI Materials Journal, 107(6)

xi. Drying Shrinkage of Heat-Cured Fly Ash-Based Geopolymer Concrete Steenie Edward Wallah Department of Civil Engineering, Faculty of Engineering Sam Ratulangi University, Indonesia

xii. Low calcium fly ash geopolymer concrete – A promising sustainable alternative for rigid Concrete road furniture D S Cheema, Main Roads, Western Australia

xiii. Utilisation of fly ash in a geopolymeric material J.C. Swanepoel, C.A. Strydom Department of Chemistry, University of Pretoria, South Africa

xiv. Recent research geopolymer concrete.Nguyen van chanh- Assoc. Professor. Phd., bui dang trung, dang van tuan- University of technology, Vietnam

xv. IS: 456-2000, Code of practice for plain and Reinforced Concrete.

xvi. IS: 10262-2009, Concrete Mix proportioning – Guide lines.

xvii. IS: 383-1970, Specifications for coarse and fine aggregates from natural sources for concrete.

xviii. IS: 3812-2003, Specifications for fly ash use as pozzolana and admixture.

xix. Mix design and production of fly ash based Geopolymer concrete by Prof. Vijayarangan. B, The Indian Concrete Journal, May 2008.

xx. Recent Advances in Paper Mill Sludge Management Marko Likon and Polonca Trebse Insol Ltd, Postojna,University of Nova Gorica, Nova Gorica, Slovenia.

xxi. Reuse of Paper Mill Ash in Plaster Blends. Saveria Monosi, Daniela Sani and Maria Letizia Ruello.

xxii. Environmental quality of primary paper sludgeMaria Rosaria Boni, Laura D'Aprile, Giancarlo De Casa.

xxiii. Potential of wastepaper sludge ash to replace cement in deep stabilization of quick clay P. M. S. Bujulu, A. R. Sorta, G. Priol & A. J. Emdal Department of Civil and Transport Engineering, Geotechnical Division, NTNU, Norway

xxiv. Sunjay Kumar, Rakesh Kumar, Mechanical activation of fly ash: Effect on reaction, structure and properties of resulting Geopolymer, Ceramic International (2011).

xxv. Sumit A Balwaik, S.P.Raut. Utilization of waste paper pulp by partial replacement of cement in concrete, International journal of Engineering research and applications (2011)