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Influence of Paper Sludge Ash on the Mechanical Properties of Fly Ash Geopolymer Concrete

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Abstract: Concrete is the most abundant man made material in the world. One of the main ingredients in a normal concrete mixture is Portland cement. The production cement from industries emits green house gases and Co_2. On the other hand paper mill sludge is the major economic and environmental problems for paper industry. Annual paper sludge disposal of paper industry in global level is 7.1 metric ton. Reduce the usage of cement fly ash based geopolymer concrete is used. Owing to the scarcity of fine aggregate paper sludge ash partially replaced for fine aggregate in various proportions (0%, 10%, 20%, 30%). The various tests such as compressive, split tensile and flexural strength test are to be conducted.
Key Words: Paper sludge ash; fly ash; geopolymer; mechanical properties

I. INTRODUCTION

The global warming is an environmental problem caused due to the emission of greenhouse gases such as Carbondioxide (CO2) to the atmosphere cement industry held responsible for some of the CO2 emission. Producing one tonne of cement requires about two tonnes of raw materials and releases 0.87 tonne (1 tonne of CO2)about 3kg of Nitrogen oxide an air Contaminant that Contributes to ground level smog and 0.4 kg of PM10 (particulate matter of size 10um) an air borne particulate matter that is harmful to the respiratory tract when inhaled. The global release of CO2from all sources is estimated at 23 billion tonnes a year andthePortlandcementproductionaccountsforabout7%oftotal CO2 emission. In terms of reducing the global warming the geopolymer technology could reduce the Carbon dioxide emission to the atmosphere caused by cement about 80%. In this work fly ash and paper sludge ash based geopolymer is used as the binder instead of Portland or and other hydraulic cement paste to produce Concrete. The fly ash and paper Sludge ash based geopolymer paste binds the loose Coarse Aggregates , fine aggregate and other an related materials together to form the geopolymer Concrete. Disposal of paper mill sludge is a major solid waste problem for the paper industry. The increases in recycled paper Content has resulted in an increase in the ash Content and a Corresponding reduction in the organic matter Content From 80-90% to 60-70%. Owing to the Scarcity of fine aggregate for the preparation of Concrete Partial replacement of paper Sludge for fine aggregate in various proportions (0%, 10%, 20%, 30%) and the work Conducted on M35 grade mix.

GEOPOLYMER

Geopolymer an Inorganic alumina-Silicate polymer having potential to from substantial element of an environmentally sustainable Construction. It gets synthesized from materials of geological origin or by product materials Containing both silica and alumina. Alkali activators play a major role in producing geopolymers by dissolving silica and alumina from the raw material and forming alumina-silicate structures. Several waste materials containing silica and alumina sources like red mud, silica fume, GGBS and fly ash could be used as a source material to produce geopolymer concrete.

APPLICATION OF GEOPOLYMER CONCRETE

Fire resistance Insulated panels and walls Foamed Geo- polymer panels for thermal insulation Energy low ceramic tiles Geo-polymer cement and concrete Precast concrete products like railways sleepers, electrical power poles Protective coatings Fire resistance and fire proof compose for infrastructure repair and strengthening.

ADVANTAGES

It reduces permeability and gives high life span. It is stronger, more resistant to chemicals and corrosion. It has abundant raw materials resources. Eco- friendly to environment and energy saving. Low calcium fly ash based Geopolymer concrete has excellent compressive strength and is suitable for structural application. It is most advanced in precast applications due to the relative ease in handling sensitive materials. Good volume stability, low thermal conductivity and having high fire resistance.

FLY ASH

Fly ash is one of the most abundant materials on the Earth. It is also a crucial ingredient in the creation of geopolymer concrete due to its role in the geopolymerization process. Fly ash is a powdery pozzolan. A pozzolan is a material that exhibits cementations properties when combined with calcium hydroxide. Fly ash is the main by-product created from the combustion of coal in coal- fired power plants ash, class and Class. Each class of fly ash has its own unique properties. Class fly ash is created from the burning of either anthracite or bituminous coal. This class of fly ash has little to no self cementing properties and contains very little calcium oxide (also known as lime). In order to apply class fly ash in concrete, it must be combined with some type of cementing agent, such as Portland cement, and must also be combined with an air-entraining ad mixture. This is not a very economic process if it is going to be made into ordinary concrete. Class C fly ash, on the other hand, is produced through the combustion of lignite or subbituminous coal. Unlike classF fly ash, it has self cementing properties and a much higher lime concentration which makes it ideal for use in ordinary Portland cement based concrete.

USES OF FLY ASH IN CONSTRUCTION

Improving workability without increasing water requirements. Increase the pump- ability of concrete. Increased life cycle expectancy. Resistance to sulphate, acid, salt and alkali- silica reaction Attack. Increased durability. Reduced efflorescence. Higher strength. Decreased permeability.

PAPER SLUDGE ASH

Paper mill sludge is a major economic and environmental problem for the paper industry. The main recycling and disposal routs for paper sludge are land spreading as agricultural fertiliser. In functional terms paper sludge consists of cellulose fibres, filler such as calcium carbonate and china clay and residual chemicals bound up with water. After incinerating paper sludge at approximately 800°C, the resultant fly ash may content reactive silica and alumina (In the form metabolic) as well as lime (CaO) which contribute chemically to the Portland cement ingredients.

PRESENT SCENARIO OF PAPER SLUDGE 1.8.1 GLOBAL LEVEL

In 2003 world paper production reached 403 metric ton the worlds three largest paper producing countries are china, the united states and Japan the leading paper importing and exporting countries are Germany and united states. Paper industry in Canada produces about 7.1 Mt of Sludge and most of the sludge is disposed through Combustion and land filling. Production of 1 ton of paper generates about 30kg of primary sludge. India Produces 10.11 million tons paper per annumwhichis2.6%ofworldsoverallproductionquantityof paper. India is one of the fastest growing paper market in the world with a growth rate of over 10% per year in per capita Consumption.

OBJECTIVES OF THE STUDY

The objective of the project is to study the flexural behaviour RC beam using fly ash and paper sludge ash based geopolymer concrete. To cast specimen according to the standards. To cast specimen for the strength properties of concrete. To investigate the load deformation characteristic, load carrying capacity, failure mode, ductility, and crack pattern of geopolymer beam.

II. LITERATURE REVIEW

Ashwini. NM, Moorthy. NJ made a Experimental study on Flexural Behaviour of Fly ash based Geopolymer Concrete with GGBS . In this study,in order to reduce the usage of cement, supplementary cementing materials like fly ash and GGBS and instead of water, Alkali solution have been introduced in the name of Geopolymer concrete. Geopolymer concreteisal so much more durable that ordinary concrete due to its resistance to corrosion. In this paper an attempt is made to study flexural and elastic properties of geo polymer concrete using low calcium fly ash replacing with GGBS in 5 different percentages as (100%:0%),(90%:10%),(80%:20%), (70% : 30%), (60% : 40%). Sodium silicate (103 kg/m3) and sodium hydroxide of 8 molarity (41kg/m3) solutions were used as alkaline solution in all 5 different mixes. The investigations were carried for the Compressive strength, Split tensile strength, Flexural strength test on the concrete specimens. The specimens were cured at ambient temperature and tested at 7th and 28th days. From the test results, it was observed that the maximum strength was obtained for mix with 30% GGBS and 70% flyash. As the strength of concrete increases, there is decrease in the ratio. The Modulus of elasticity values increases with increase in compressive strength of geopolymer concrete.

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S.Kumaravel, S.Thirugnanasambandam studied the of geopolymer concrete beams. In this study, low calcium Fly ash based is a by-product from the coal industry, which is widely available in the world. Fly ash is rich in silicate and alumina, hence it reacts with alkaline solution to produce alumina silicategel that binds the aggregate to produce a good concrete. The compressive strength increases with the increase is fly ash fineness and thus the reduction in porosity is obtained. The flexural behaviour of geopolymer concrete (GPC) beams and control cement concrete beams are studied. The beams are cast over an effective span of 3000 mm and tested up to failure under static loads. The load-displacement response of the geopolymer concrete beams and control beams are obtained and compared with the theoretical results. The results show that the geopolymer concrete beams exhibit increased flexural strength. The deflections at different stages including service load and peak load stage are higher for GPC beams.

Sanjay R, Dr. M.U. Aswathmade an investigation on An Experimental Study on Flexural Behaviour of Reinforced Geopolymer Concrete Beams with Recycled Aggregate in Bending. In this study the industrial by-products comprising of fly ash and Ground Granulated Blast Furnace slag (GGBS) were geopolymerised by sodium silicate and sodium hydroxide (NaOH) solution. Recycled aggregate completely replaced the conventional coarse aggregates in the geopolymer concrete. All the specimens were tested on the 7thday after casting. As the compressive strength was found to increase with the increase in NaOH molarity, an optimum molarity of 12M was adopted. Experimental investigations showed that the inclusion of GGBS by 10% by mass in the binder material increased the compressive strength by 23 %. The effects of variation of binder percentage on workability, compressive strength, flexural strength and split tensile strength were analysed. Most promising results were obtained when the binder content (flyash 8 + GGBS) were 27% of the total solid constituents of the geopolymer concrete mix using recycled aggregate. Results of compression test showed a decrease in strength of about 10% compared to the conventional coarse aggregate. Adopting 27% of the binder content with 12M NaOH molarity, beams were casted and tested for the load deflection behaviour, ultimate load and crack width. The workability is also affected by the type of coarse aggregate used in the concrete. Mix with recycled aggregates gives lesser slump when compared with conventional aggregates. The compressive strength, flexural strength and split tensile strength increases with increase in binder content upto certain limit and shows decrement in strength with further increase of binder content Increase in molarity of sodium hydroxide increases the compressive strength of geopolymer concrete. The compressive strength of geopolymer concrete with recycled aggregates is lesser than that of the compressive strength with conventional coarse aggregates. The decrease in strength is about 10-15%, which is lower than the value compared with OPC concrete. Addition of GGBS by 10% mass of binder increases the compressive strength by 23 %.

Adriano Battaglia, et al., performed Paper mill sludge soil mixture: kinetic and thermodynamic tests of cadmium and lead sorption capability In this study Paper mill sludge (characterized by 29.0% of organic substances such as cellulose, lignin and tannins and 71.0% of inorganic substances such as kaolinite and carbonates) was studied in a mixture with soil in order to evaluate its effects on soil capability for retaining heavy metals. Attention was focused on cadmium and lead sorption and two parameters were investigated, the contact time of paper mill sludge soil mixture and the paper mill sludge soil ratio in the mixture. Results showed that paper mill sludge and lead, there tention of which by soil is substantially increased by sludge addition, 9 can highlight this modification. Also, the amount of sorbed cadmium was increased by sludge addition. 5. Ambily.P.S, Madheswaran.C.K (2007) performed Experimental and analytical investigations on shear behaviour of reinforced geopolymer concrete beams. In this paper, describes an experimental and analytical investigation on shear behaviour of reinforced GPC and OPCC beams. The aim is to study the shear behaviour of reinforced GPC and OPCC beams. Three GPC mixes and one OPCC mix were considered for the study. All the beams were provided with the same flexural and shear reinforcement and the beams were tested under two point loading with two shear span to depth ratios of 1.5 and 2 for each of the mixes. This paper presents the details of the mix designs of GPC mixes, parameters investigated, preparation of RGPC beams, testing and evaluation of structural behaviour with respect to cracking, service load, deflections at various stages and failure modes. Comparison of shear design procedure of beams was made by conventional IS 456 2000 approach and Modified compression field theory. Non-linear finite element analysis of beams by 3D modelling of concrete (solid65 element) and discrete modelling of reinforcement (Link8 element) was carried out using ANSYS software. For shear span to depth ratio of 1.5, load shear capacity, load deflection characteristics and failure modes and crack patterns obtained from the experimental and analytical study were compared for both RPCC and RGPCC beams. The results of the study indicate that the performance of RGPC is similar to that of RPCC beams and the ultimate loads are in the same order. The failure modes and crack patterns are also similar. The ultimate load capacity of the GPC beams was only 15 % more than the OPCC beams in spite of a 20% higher compressive strength. As expected, the shear capacity of the beams was influenced by the av /d ratio and the concrete compressive strength .The shear capacity increased only marginally when the compressive strength of concrete 10 increased and the ultimate moment carrying capacities of beams normalized with respect to compressive strength are of the same order. The test results showed that the cracking load determination methods used for finding cracking moment of OPCC beams GPC beams are inadequate as they are based only on the modulus of rupture.

Sherin kurikesu, Abhirami made an investigation on Experimental and Analytical Study on Geopolymer Concrete Beam with Hollow Space below Neutral Axis. In this study this paper focuses on the material minimization by introducing hollow space using PVC pipe in tension zone of beams. By this method, we can reduce the dead loads which contribute to seismic effect in high rise structures. Geopolymer concrete shall be produced without using any amount of ordinary Portland cement. Alkaline solution produced aluminosilicate gel that acts as the binding material for the concrete. Thus many efforts are being made to reduce the usage of opc which responsible for carbon dioxide emission. M30 grade concrete is used for ordinary and geopolymer concrete. Experimental validation was done by ANSYS software. Mode of failure is flexural in hollow beam of 25mm and flexure in solid and hollow (32mm). It is seen that there is not much difference in the flexural strength of control beams and that of beams with low grade concrete near neutral axis zone and hollow neutral axis. It can also be seen that with the increase in size of pipe replaced at neutral axis, there is no large difference in flexural strength.GPC has almost same properties as that of OPC. From the above results, it is concluded that Hollow beam of 25mm and 32mm diameter provides higher strength and better performance and hence it is used for structure in effective way as electrical conduits, when compared to the solid conventional beam.

Senthamilselvi Pachamuthu, Palanisamy made a Effect of incinerated paper sludge ash on fly ash-based geopolymer concrete. In this study, the development of fly ash and incinerated paper sludge ash blend as a source material for preparing geopolymer concrete is presented in the paper. The specimens were prepared with varying percentage of fly ash replaced by paper sludge ash under different curing regimes. The compressive strength, splitting tensile strength, and bending strength values were tested and geopolymer microstructure was analysed. The up to 10% increase in strength of geopolymer concrete containing fly ash and paper sludge ash shows that good prospects exist for the use of this type of concrete for cast-in-situ applications. The effect of adding PSA to the fly ash based GPC on the mechanical and microstructure properties was investigated in this study. Oven cured non-PSA specimens yielded maximum strength compared to the non-PSA samples under EEC and AC conditions. The addition of PSA in FA GPC decreases mechanical strength under OC conditions. Hence, the use of this material is not suitable under this curing condition. The addition of PSA in the FA GPC improves mechanical properties under both. EEC and AC conditions. Beyond 10 % addition of PSA, there is a decline in the mechanical strength under EEC and AC conditions. The characteristic of 35 MPa was achieved under all the three curing conditions of the fly ash-PSA-based GPC specimens. The results under AC and EEC conditions showed that geo polymer technology can be used in the cast-in-situ concrete construction. The test results were also confirmed by the SEM observation.

Dr.Andrew MDunster (2007) studied the Paper sludge and paper sludge ash in Portland cement manufacture . In this study includes the use of the fly ash from combined heat & power (CHP) combustion of paper sludge (as a cement clinker input material) and the sludge itself (as an alternative liquid fuel). Further details of the role of alternative raw materials (ARM) and fuels in 12 cement manufacture are given in the MINRES project cement sector study. Paper sludge and paper sludge ash are potentially useful products in the manufacture of cement and in blended cement. There is a large supply of paper sludge ash available from industrial CHP plants. A quality protocol for the ash material is being considered as part of the Quality Protocols programme. The properties of the sludge itself could be improved by processing. could potentially open up higher value applications for the material as described in reference.

Srishti Saha, Purnachandra Sahamade an investigation on Structural Behaviour Fly ash and Ferrochrome ash Based Geopolymer Concrete with Recycled Aggregate . In this paper deals with the structural behaviour of reinforced concrete beam made with different percentages of recycled aggregate as coarse aggregate on an ovel geopolymer concrete consist of fly ash and ferrochrome ash as binder. Structural behaviour of RCC beam with 10% and 20% recycled aggregate in geopolymer concrete are studied and compared to the 100% natural coarse aggregate. Experimental results revealedthattheupto10%replacementofrecycledaggregate can achieve strength equal to control concrete and it can be the recommended percentage of RCA for concrete industry. The paper studies the structural behaviour of fly ash and ferrochrome ash based geopolymer concrete by using recycled aggregates as coarse aggregate. Beams were prepared with 0%, 10% and 20% as partial replacement by recycled aggregates and tested for flexures. From the test results obtained, following conclusions are deduced. All specimens failed due to shear failure since the length of the beam is so small. The entire beam shows good ductility and conveyed adequate warming before failure. Among the beam samples with recycled aggregates, specimen with 10% recycled aggregate provides maximum strength. Recycled aggregates, fly ash and ferrochrome ash, all three are waste materials used for making geopolymer concrete, experimental results revealed 13 that the up to 10% replacement of recycle aggregate have comparable strength of natural coarse aggregate and it is the recommended percentage of RCA suitable in concrete industry.

Yifei Cui, Kaikai Gao and Peng Zhang(2020) made a investigation on Experimental and Statistical Study on Mechanical Characteristics of Geopolymer Concrete. In this study statistical correlation in mechanical characteristics of class F fly ash based geopolymer concrete (CFGPC). Experimentally measured values of the compressive strength, elastic modulus and indirect tensile strength of CFGPC specimens made from class F fly ash (CFA) were presented and analyzed. The results were compared with those of corresponding ordinary Portland cement concrete (OPCC) using statistical hypothesis tests. Results illustrated that when possessing similar compressive and tensile strength, the elastic modulus for CFGPC is significantly lower than that of OPCC.

The corresponding expressions recommended by standards for the case of OPCC is proved to be inaccurate when applied in the case of CFGPC. Statistical regression was used to identify tendencies and correlations within the mechanical characteristics of CFGPC, as well as the empirical equations for predicting tensile strength and elastic modulus of CFGPC from its compressive strength values. In conclusion, CFGPC and OPCC has significant differences in terms of the correlations between mechanical properties. The empirical equations obtained in this study could provide relatively accurate predictions on the mechanical behavior of CFGPC. This study mainly presents the investigation into three essential mechanical characteristics of fly ash based geopolymer concrete (CFGPC). These are the compressive strength, the indirect tensile strength and the elastic modulus. The experimental results were compared with corresponding ordinary Portland cement concrete (OPCC). The correlations between compressive strength and elastic modulus or indirect tensile strength were determined by statistical regression. It was found that the 14 current provisions used for predicting the indirect tensile strength of OPCC do not accurately apply to CFGPC. It is noticed that the tensile strength of CFGPC increased in an approximately proportional manner with the increase in compressive strength, and the correlation was basically linear, where as for OPCC, the correlation followed a non-linear relationship. The correlation between the tensile and compressive strength of CFGPC is therefore better expressed using a suggested statistically derived equation, which produced predicted values that preferably compared with those predicted using the current provisions. 2. The statistical hypothesis testing illustrated that when the compressive strength of the CFGPC mix and the OPCC mix is between 30 MPa and 40 MPa, there is no significant difference in their indirect tensile strength values. owever, in this strength range, CFGPC statistically significantly lower than that of the OPCC mix. 11.Anil Kumar, Devika Rani(2013) studied the Performance of Concrete Using Paper Sludge Ash and Foundry Sand . In this study the wastes generated it is presumed that 10%-15% of wastes are hazardous and increasing at the rate of 2% - 5% per year, resulting in environmental pollution and effect to living beings. These wastes can be utilized as alternative construction material, so that it would be one of the consistent ways of disposal. This paper attempts to study the strength parameters such as compressive and tensile strength of Paper Sludge Ash (5%, 10%, and 15%) as a partial replacement of cement and Foundry Sand (20%, 40% and 60%) as a partial replacement of fine aggregate for a design mix of M25.As per the results obtained based on the characteristics of materials say, Workability of Concrete, Compressive Strength Test, SplitTensileStrengthTestandFlexuralStrengthTestonM25 grade of concrete, made of different mixes with 20%, 40%and 60% replacement level of Waste Foundry Sand and 5%.10% and 15% replacement levels of Paper Sludge Ash, considered for the study the following conclusions are been listed. Based15 on the compressive strength of specimen with different replacement level these conclusions were found i. For the grade of concrete considered for the study, FS2 i.e.the ratio of 60:40 of Conventional Sand, Foundry Sand has proved to be having optimum ratio which gives maximum Compressive strength of all ratios. Specimen of Conventional Concrete bearing the designation CC resulted in highest compressive strength at 7 days, 14 days and 28 days of curing period, of all the mixes considered for the study. At the higher replacement levels i.e. at 60% foundry sand replacement, 28 days strength is 8.16% greater than that of CC concrete mixing.

III. COLLECTION OF MATERIALS

Collection of Materials like Cement, M-sand ,Coarse Aggregates, Fly ash, Paper Sludge Ash.

TESTING ON MATERIALS

CEMENT TESTING

Cement is made by grinding calcined limestone and clay into a very fine, grey powder. Cement is one of the binding agent in this project. The cement and water forms a paste and binds the other materials together. The Ordinary Portland Cement (53 grade) conforming to IS:8112-1989 is being used. Many tests were conducted on cement. 18 The following tests are conducted, Consistency test Initial and final setting time Soundness test

COARSE AGGREGATES TESTING

Coarse aggregate consists of crushed granite or basalt rock, conforming to IS:383. Coarse aggregate are used in the size of 20mm. Sieve analysis Fine modulus Impact test Gravity test Water absorption &moisture content Specific surfaces &surface index Clay, slit content

FINE AGGREGATES TESTING

Fine aggregate used throughout the work comprised of clean M.sand with maximum size of 4.75mm conforming to Zone I as per IS 383- 1970. M.Sand is naturally occurring granular material composed of finely divided rock and mineral particles. Those fractions from 4.75 mm to 150 microns are termed as fine aggregate. The M.sand sand is washed and screened, to eliminate deleterious materials and oversize particles. Sieve analysis Specific gravity test Water absorption &moisture content Bulk density voids. PAPER SLUDGE ASH The sludge which was used in this study collected from paper industry. The Sludge was collected directly from drying beds by random sampling in plastic bag. Each bag contains 20 kg of sludge. The collected sludgehadnearabout15-20%ofmoisturecontent.So,Sludge was dried in direct sunlight for making it moisture free and then grinding was done using mechanical methods. Thus care should be taken while drying and grinding it.

FLYASH TESTING

Fly ash is the main by product created from the combustion of coal in coal Class C. Each class of fly ash has its own unique properties. Chemical composition of fly ash are

IV. EXPERIMENTAL INVESTIGATION

TESTS ON HARDENED CONCRETE

The following tests are conducted to determine the mechanical properties of concrete specimens.
Compressive strength test, Splittensile test, Flexural strength test

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COMPRESSIVE STRENGTH OF CONCRETE

The compressive strength of the prepared concrete specimens cubes of 150x150x150 mm size of M35 grade were determined using the Universal testing machine and their results are been analyzed. After completing the curing period of test specimens were kept in dry place for few hours to attaining surface dry condition. The specimen is placed at the center of the pads located at the top and bottom portion of compression testing machine. Switch on the machine and apply the load at the uniform rate till failure occurs and note the maximum load at failure.

Compressive strength test=Applied load (N)/Area of the specimen (mm^2)

Fig.4.1 Testing of cubes in UTM Table 4.1 Values of Compressive Strength test

%	Compressive strength test (N/mm^2)			
	Trial1 N/mm^2	Trial2 N/mm^2	Trial3 $/mm^2$	Mean N/mm^2
0	39.61	38.24	38.25	38.7
10	39.83	40.79	41.61	40.74
20	42.71	41.26	42.50	42.15
30	39.54	40.11	38.73	39.66

SPLITTENSILE TEST

The test is carried out by placing cylinder specimen of dimension 150mm diameter and 300mm length, horizontally between the loading surface of compression testing machine and the load is applied until failure of the cylinder along the vertical diameter. The failure load of the specimen is noted. The failure load of tensile strength of cylinder is calculated by using the formula.

Tensile strength=2P/3.14DL

Fig.4.2 Splittensile test on concrete cylinder

Table 4.2 Values of Split Tensile test

%FA	%PSA	Split Tensile test (N/mm^2)			
		Trial1 N/mm^2	Trial2 N/mm^2	Trial3 N/mm^2	Mean N/mm^2
100	0	4.89	4.90	4.88	3.89
90	10	4.10	4.06	4.05	4.07
80	20	4.34	4.30	4.30	4.31
70	30	3.93	3.90	3.91	3.92

FLEXURAL STRENGTH TEST

The test is carried out to find the flexural strength of the prism of dimension100x100x500mm.The prism is then placed in the machine in such manner that the load is applied to the upper most surface as cast in the mould. Two points loading adopted on an effective span of 400 mm while testing the prism. The load is applied until the failure of the prism. By using the failure load of prism

$$\text{Flexural strength} = PL/bd^2$$

Fig. 4.3 Flexural Strength test on prism

Table 4.3 Values of Flexural Strength test

%FA	%PSA	Flexural Strength test (N/mm^2)			
		Trial1 N/mm^2	Trial2 N/mm^2	Trial3 N/mm^2	Mean N/mm^2
100	0	4.21	4.26	4.43	4.25
90	10	4.41	4.50	4.46	4.43
80	20	4.65	4.67	4.63	4.64
70	30	4.14	4.11	4.14	4.13

V. RESULTAND DISCUSSION

COMPRESSIVE STRENGTH TEST RESULT

20% partially replacement of paper sludge ash records higher values in terms of compression.
15.8% is increase in compressive stress is observed in 20% replacement specimen when compared to control specimen.
At30%partialreplacementpapersludgeashtofine aggregate decrease in strength observed.

SPLITTENSILE TEST RESULT

In split tensile test 20% partial replacement of paper sludge ash records higher values compared to conventional.
Increasing the percentage of paper sludge ash partial replacement to fine aggregate decrease the strength of the specimen.

FLEXURAL STRENGTH TEST

20% partial replacement of paper sludge ash records higher values.
Increasing the percentage of paper sludge ash to fine aggregate the strength is decrease.
At 30% partial replacement of paper sludge ash to fine aggregate the strength is start to decrease.

VI. CONCLUSION

As per the results obtained from testing the specimen compressive strength test, split tensile test, Flexural strength test on M_{35} grade of concrete made of different mixes with 10%, 20%, 30% replacement level of paper sludge ash , considered for the study the following conclusions are listed.
From the test results it was observed that 20% replacement of paper sludge ash is found to be optimum.
In 30% replacement of paper sludge ash strength is start to decreasing.
Compressive strength test, Split tensile test, Flexural strength test results are increased in 20% replacement with paper sludge ash.
Increasing the level of paper sludge ash the strength is decrease.

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