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Partial Replacement of Cement with Wood Ash & Fly Ash in Pavement Quality Concrete

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Abstract*: Pavement Quality Concrete (PQC) is a special type of concrete which is used for construction of rigid pavements in dense traffic regions. In this type of PQC higher percentage of cement content is added when compared with conventional concrete, and it is mostly designed for high strength concrete M40 to M50 grade of concrete. Cement production leads to emission of greenhouse gases in vast amount, which made researchers to look for an substitute material to incorpotate with cement. The current experimental work is done to study the effect of wood ash and fly-ash mixed in concete as a partial replacement of cement. The replacement levels of wood ash and fly ash are taken equally as 10, 20 and 30% by weight of cement. In this mainly focused on Compressive strength and split tensile strength according to IS Codal provisions. Experimental test results revealed that the replacement of wood-ash and fly ash as a cementitious material in Pavement Quality Concrete will improve compressive and split-tensile strength of concrete.

***Keywords*: Cement, Concrete, Flyash, Pavement Quality Concrete, Wood ash.**

I. INTRODUCTION

Pavement Quality Concrete (PQC) is a type of rigid pavement used in areas with dense traffic volume and where the application of load is rapid and more. It is mostly used in Aprons of airport. PQC is a concrete slab which is generally designed of M40 to M50 grade of concrete as per Indian specifications with a varying thickness of 150mm to 300mm. The material Composition of this slab includes OPC (53 Grade), fly-ash, fine, coarse aggregate and water content. The increase in industrialization, the industrial waste materials are being stockpile in large extent and leads to environmental problem which relates to the discard by land filling. Wood-ash is collected from combustion method done in boilers of pulp and paper industries. Burning of saw dust which turns in to wood ash is use as a partial substitution of cement and which alter physical and chemical properties of concrete and these properties are similar to fly-ash.

Research have done separately on utilization of wood ash and fly ash replacement of cement in concrete. According to Dona et al. [1] It is commonly observed that high quantity of ash will be produced from hardwood when compared with softwood as well bark and leaves also produce more in comparison with inner part of trees. In the Dona et al. experimental work materials like Portland pozzolana cement (PPC), coarse aggregate (CA) and wood-ash in varying proportions of concrete mix with replacement of 3%, 5%, 8% by weight of cement. The control-mixture was prepared with water content of 0.45. The work has been done for a target-mean strength of 31.6 N/mm^2. It has been tested and observed that 7-days compressive strength of cube with 3 varying percentages satisfies the required strength. It also noticed that 8% substitution of cement with wood-ash was found low strength to that of control specimen. Authors suggested that 5% replacement of wood ash is more suitable. S. Barathan And B. Gobinath [2] explored the potential of wood ash in construction industry by replacing wood ash of size less than 75 micrometer. Wood ash was replaced by weight percentage of 10%, 20% and 30%. The materials used in this are Portland pozzolana cement (ppc), coarse aggregate and wood ash. The authors concluded that pozzolanic properties are observed in concrete with the application of wood ash. It demands more water content with the increase in addition of wood ash percentage in concrete. At 20% replacement of wood ash (WA) specimen represents greater degree of hydration and compressive strength than ordinary Portland cement. It can be concluded that 20% is the optimum percentage to replace wood ash in concrete which will be the reference for the construction industry. According to T G S Kiran & M K M V Ratnam [3] CO_2 emissions generated by the cement industry during the manufacturing process which is about 5% emission in to the environment. This CO_2 emissions can be decreased gradually if cement is replaced by fly ash. In this research authors did experimental work on application of fly ash and have been tested for chemical and physical characteristics. In this work authors consider to replace the cement in the ratio of 0, 5, 10, 15, and 20% by weight in concrete. Compaction factor tests was done for the workability and strength tests like compressive Strength at the age of 28, 60, 90 days. Also, the specimens were tested for sulphate attack for its durability of concrete. From the results it is observed that durability of concrete is improved with fly ash addition in concrete. Jayesh Kumar et al. [4] used fly-ash as a binding material in concrete to alter the properties of conventional concrete. In this author replace the cement by fly ash with 10, 20, 30 & 40% by weight of cement for M-25 and M-40 concrete mix. Concrete specimens were casted and tested for compressive and split strength with the comparison of conventional concrete.

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He compressive strength test was done for 28 days and split tensile test was done for 56 days. Vinit et al. [5] The author conducted a study on the utilization of different materials which can fulfill the expectations of the construction industry.

In this study, cement has been replaced by fly-ash in different percentages in the range of 0, 10, 20, 30, 40, 50, and 60 by weight of cement for M-25 grade of concrete mix with water cement ratio of 0.46. Concrete mixtures were casted, cured and tested for 28 days and compared with normal concrete. It was observed that 20% replacement of cement by fly-ash strength is enhanced from 1.9% to 3.2% at 28 days and 56 days respectively. It was observed that up to 30% replacement of cement by fly-ash strength is almost equal to 56days concrete strength. The strength gained is very slow due to the hydration process. PPC gained strength after 56days curing because of slow hydration process. In the current research work, the concrete mixes are replaced with the amorphous wood ash as an admixture of cement having grain size of 90 microns in proportions of 10%, 20%, 30% and also equivalent percentage of fly ash by replacing the cement in terms of weight. In this, experimental work is conducted for determining the workability, compressive and split tensile strength and also durability tests for M40 grade of concrete.

II. EXPERIMENTAL PROGRAM

Port land cement was replaced with varying percentages of fly-ash and wood ash. The details of concrete mixtures used in the investigation are shown in Table 1.

Table 1: Details of Concrete Mixes

Mix	Cement kg/m^3	Fine Aggregate kg/m^3	Course Aggregate kg/m^3	Water Content kg/m^3	Fly Ash kg	Wood Ash kg
OPC	450	745.8	1009.94	180	-	-
OPC – 5% Wood Ash & 5% Flyash	351.45	803	1087.85	142	19.52	19.52
OPC – 10% Wood Ash & 10% Flyash	112.4	796.4	1078.47	142	39.05	39.05
OPC – 15% Wood Ash & 15% Flyash	273.35	792.66	1072.51	142	58.57	58.57

2.1 MATERIALS USED AND TESTS CONDUCTED

Ordinary Portland cement with specific gravity of 3.15, Fine aggregate (FA) specific gravity of 2.5, coarse aggregate (CA) specific gravity of 2.66 were used. Along with the above material's chemical admixtures sodium hydroxide and sodium silicates were added to increase the binding nature of cement. Concrete cube specimen of 150 x 150 x 150 mm size was used to determine the compressive strength of concrete. Initially Ordinary Portland cement of 53 grade was only used in preparation of concrete specimen which we call as conventional concrete and then the cement was replaced by 10%, 20% & 30% of fly ash and wood ash in equal proportions. The concrete specimens are then demoulded and set for curing.

2.1.1 Compressive Strength Test

The replacement percentage of cementitious materials is 10%, 20%, 30% by cement in terms of weight. Tests were performed for 7-days and 28-days using Compressive Testing Machine (CTM). The compressive strength of any material is defined as the resistance to failure under the action of compressive forces. The compressive strength of concrete is determined in terms of the characteristic compressive strength of 150 x 150 x 150 mm size cubes tested at 28 days (f_{ck}). The characteristic strength is defined as the strength of the concrete below which not more than 5% of the test results are expected to fall. The compressive capacity of concrete is calculated using the formula.

Compression capacity = Load at Failure / Area of Loading

2.1.2 Split Tensile strength Test

As concrete is a brittle and it is weak in tension. When tensile forces exceed its tensile strength, cracks are formed. So, determination of split tensile strength at which the concrete crack is major test. Split tensile strength is a method of finding out the tensile- strength of concrete which is done as follows and load is applied as shown in "Fig. 1".

$$T = 2P/\pi LD$$

Where, T = split tensile strength (MPa), P = Max. load applied (N), D = specimen diameter (mm), L = Specimen Length (mm).

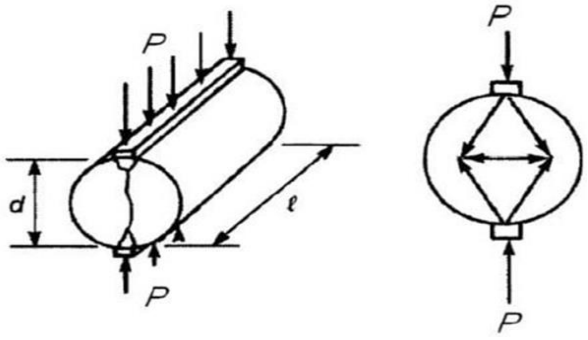

Fig. 1: Split tensile strength test on cylindrical specimen

III. RESULTS AND DISCUSSIONS

The compressive strength readings of different concrete mixtures that are made from ordinary port land cement and different percentages of wood ash and fly ash for 7 and 28 days are shown in Table 2.

Table 2: Compressive Strength Test Results

S.No	Replacement of cementitious Material	7 Days N/mm^2	28 Days N/mm^2
1	0%	35.48	47
2	10%	30.92	49.7
3	20%	27.22	52.5
4	30%	25.66	40

From the results it is observed that, with the application of wood ash and fly ash in concrete mix there is an enhancement in the compressive strength but the increase was not up to the control specimens.

The ductile behavior of concrete with replacement of wood ash was improved which is tested under compressive testing instrument. It is also observed that wood ash specimen takes more time to break the specimen when compared with control specimen, Also clearly observed cracks developed slowly in control specimen when compared to wood ash specimen.

The split tensile strength values of different concrete mixes that are made from ordinary port land cement and different percentages of wood ash and fly ash for 7 and 28 days are shown in Table 3.

Table 3: Split Tensile Strength Test Results

S.No	Replacement of cementitious Material	7 Days N/mm^2	28 Days N/mm^2
1	0%	2.9	3.3
2	10%	2.21	3.43
3	20%	2.12	3.63
4	30%	2.06	3.5

The Optimum test results were obtained up to 20% replacement by wood ash in the concrete specimens. The raise in the split tensile strength of concrete is due to quality of material and also addition of wood ash and fly ash. The failure was observed in control specimen of brittleness which results in to splitting in two halves whereas with the addition of wood ash in concrete the failure was observed was not sudden.

IV. CONCLUSIONS

The Experimental test results after 7 & 28 days of curing reveled the following.

1. Partial Replacement of cement with flyash and wood ash shown gradual increase in its strength.
2. Conventional concrete at 28 days, compressive strength is 47 N/mm^2.
3. At 20% replacement in which 10 % is fly ash and remaining 10% is wood ash with 7 & 28 days of curing the compressive strength was 27.22 N/mm^2 & 52.5 N/mm ^{2} respectively.
4. At 20% equal replacement of wood ash and fly ash with with 28 days of curing the split tensile strength is raised from3.3 to 3.63N/mm^2.
5. Further replacement of fly ash and wood ash leads to decrease in strength of concrete.

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