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Use of Waste Paper Sludge Ash as Supplementary Cementious Material in M20 Concrete

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ABSTRACT- In this modern age concrete and cement mortar are abundantly used in construction. Large amount of industrial waste are generated and if these wastes are not correctly used it will cause negative impact , thinking about environment, concrete engineers are trying to find out some cementitious materials which will have more strengthening ability and less impact on environment than cement.
During the processing of cement huge quantity of CO_2 is discharged into the surroundings, so to find out the replacement for cement we are approaching towards the clean and pollution free atmosphere. In the same way, during this research work we are using waste paper sludge ash as supplementary cementitious material.
The paper sludge which is the byproduct of paper mill which is obtained during the manufacturing and recycling of paper. By using of waste paper sludge in concrete as supplementary cementitious material also increases strength in the concrete like compressive, flexural and split tensile strength. The paper sludge ash is used in the concrete in different values from varying percentage of 2% to 10%. During the manufacturing of the concrete all the codes have been followed for mixing .In this manufacturing process cubes of size (150*150*150) mm and cylinders of (150*300) mm were made with the change in percentage of WPSA. The specimens which were casted were properly cured and all the tests were conducted on them. The test which was performed on the samples were split tensile, Flexural, Compressive strength, Normal consistency test etc. It has been observed and recorded that the strength of the samples was increasing with the addition of the waste paper sludge ash.

KEYWORDS- Waste paper sludge ash, Flexural strength test, Split tensile strength test.

I. INTRODUCTION

A. General

Concrete is the most used material in the modern era for construction purposes. Concrete consists of fine and coarse aggregate and water also. The strengthening and other properties of the concrete are totally dependable on the mixture and the materials used. As the use of concrete is at peak in the modern times, so experts are trying to find out the alternative for the less use of cement and also good strengthening material in place of cement in concrete.
The main aim of minimizing the use of cement in concrete is not only to lower the cost of structure but also to protect the environment from pollution (causing during processing of cement).Durability is one of the feature of concrete which depends upon on the properties of materials used in the concrete. Waste paper sludge (WPSA) is one of the material on which work is done to minimize the use of cement and to enhance the physical and chemical properties of concrete. The use of supplementary cementitious material like WPSA in concrete is playing a vital role in the pollution free environment.
There are various countries that are working on the supplementary cementitious materials in concrete and construction technology.

B. Waste Paper Sludge

There are making lots of efforts nowadays towards the pollution free environment and for the balance of eco-system of the bio-sphere. It is being believed that environment has always risk and everyone cannot contribute towards the economic development of the era. The sustainable growth with good environmental qualities can be attained. As it is multi-dimensional so each and every one have to contribute towards the cleaner environment in one way or other way.
There is the generation of millions of tons of byproducts/wastes by different process. The generation of these wastes cause problem of disposal and have ill effects on health. The wastes from paper industries can be recycled many times till it becomes weaker and cannot make strong paper. The broken paper, low quality paper is separated and it becomes sludge later. Paper sludge has cementitious properties because of the presence of Silica and Magnesium which helps in the setting of concrete. The amount of sludge released is totally dependable upon the type of furnish being and the product which is to be manufactured. The sludge generated from the paper industries is used as a partial replacement for the fine aggregates in the processing of concrete for low budget purpose which minimize the cost of construction. About 3000kg of sludge is produced from 10 tons of recycled paper. The generation of this sludge is increasing day by day because of demanding use of paper.

This very much sludge makes land filling more economical because of bulking of sludge.

The chemical composition of dry paper sludge is Silica, calcium oxide, alumina and magnesium oxide. The consumption of landfill by the waste paper mill sludge is alarming every year. Some of the waste is spread over the agricultural land , some sludge is put in the water bodies . Sometimes it is burnt which cause severe air pollution, because of the release of the toxic gases into the atmosphere.

It is the matter of concern to reduce the land filling and pollution by these wastes to change them into alternatives and profitable materials.

Keeping in mind steps were taken to make the economical concrete by mixing varying ratios of cement with hypo sludge. At the end of nineties U.S. pulp and paper industry generated above 5 million metric tons of oven dry waste-treatment residuals which equals 16 million metric tons of moist residual. Half of this much quantity was disposed $1/4^{th}$ was burned $1/8^{th}$ was put in the land , $1/16^{th}$ was recycled.

Sludge is mainly consists of cellulose fibers, moisture, paper making fillers. The use of the industrial wastes(generated from the factories) in the construction is the main contribution towards the pollution free environment. The wastes generated from the paper industries are mostly used in the construction company to make it economic. The paper mill wastes used in construction are the alternatives to land fill.

II. METHODOLOGY

A. Material properties have been tested as per the Indian standard code (IS 383-1996)

B. Design mix for the proportion of concrete has been done as per IS 10262-1982.

C. The strength of concrete after hardening was tested as per IS 456-2000

D. Finding the optimum strength of WPSA.

III. LITERATURE REVIEW CONCRETE MIX WITH WASTE PAPER

***A. Jayeshkumar et al* (2013)** He studied utilization of hypo sludge as a supplementary cementitious material in concrete for the construction of rigid pavement. He replaced the cement by hypo sludge within the range of 10-40%. He tested 5 mixes for compressive strength, flexural strength and cost.

The result came out as :- by the use of hypo sludge in concrete the disposal and storage problem of wastes can be solved. This is the new innovation in the concrete to make it more economical. By the use of hypo sludge in road construction can make it economical.

CBR value of 2% and wheel load of 3000N for this value cost will be reduced by RS. 600.

B. Sajad Ahmad (2013) In his work, in M25 concrete the cement was replaced by 5 to 20% by waste paper sludge . He has tested the material for compressive and tensile strength and also for water absorption and dry density. He compared it with the conventional concrete also.

From the result:- by the replacement of 5% of cement by WPSA showed 10% increase in compressive strength at 7 days and 15% increase in compressive strength at 28 days. The water absorption rate increased in modified concrete. The weight of concrete decreased by the use of WPSA and made it light weight concrete . by the use WPSA in concrete makes it economical.

C. Rushabh ah shah (2013) Hypo sludge is examined for partial replacement of cement in mortar. The use of hypo sludge in the cement mortar is very beneficial in all the cases. This paper presents result of cement mortar mix proportion 1:3 in which cement has been replaced by hypo sludge up to 50% by cement weight. The compressive strength has been obtained by four sets of samples, the result showed decrease in strength for hypo sludge at 7&28 days for 1:3 mortars so, and it can be used in non-structural elements where strength is not considered at high range.

From the results:- the use of hypo sludge in place of cement does not improve bond strength at the early age of 7 days . It can be used to prepare low cost temporary structures. The result shows that 34% reduce in cost for 50% replacement in hypo sludge.

D. Gundu M., Abhay Sinha (2021) Studied the performance of concrete mix with mixing of paper waste, waste plastic, quarry dust and fly ash, in this experimental study the above materials have been used in the concrete in this experimental study cement is being replaced with 5% of fly ash, 3% paper pulp, coarse aggregate with plastic waste by 5, 10 and 15%. In this experiment all the tests have been performed according to IS codes.

From the tests and results on the materials used in the experiment the conclusions have been made are

The compressive strength of the concrete started to decrease with the plastic waste, the weigth decreased due to the addition of the paper waste , the cost of the concrete have been reduced due to the use of the wastes, the split tensile strength ist decreased and then increased with the use of plastic.

Based on the study results fly ash of 5%, paper of 3%, and plastic waste of 5%can be used in producing concrete. These wastes can be used to reduce natural resources.

E. F S Umrigar (2013) studied the use of hypo sludge and fly ash in concrete as alternative to the cement in concrete. The cement has been replaced by hypo sludge and fly ash from 0% to 40% by volume for M-25 and M-40 mix. The properties of the mixtures were tested and compared with conventional concrete. To evaluate the modulus of elasticity test were carried after 56 days . In his experiment J.K.Papers mill pvt.ltd. Provided hypo sludge.

The result showed that:- with the replacement of hypo sludge and fly ash modulus of elasticity decreased. By the use of hypo sludge and fly ash in concrete can save

disposal cost and provide "greener" concrete.The modulus of elasticity is same for M40 concrete and hypo slugged and flyashed M40 concrete . this type of concrete can be used where less strength is required.

IV. MATERIALS AND METHODS

In this chapter the information of the materials and work will be presented used in the thesis work.

A. Cement

Cement is the powdery material and is converted into the paste form by adding a suitable amount of water to it, after the sometime the paste gets changed into solid form which is termed as setting of cement. Cement acts as binding material which is having the properties of cohesion and adhesion. The constituents of the concrete are aggregates and cement. There are lots of varieties of cement that are used in the construction industry with different materials at different points. The cement is mixed with sand and is used as binding material between stones and bricks. Sometimes it is used in filling the voids which are present in between blocks or bricks. The different kinds of cements which are present in the market have different chemical composition, but in the modern times Portland cement is widely used.

The manufacturing of Portland cement is quite simple, the materials used in the manufacturing process are limestone and clay which are heated in a kiln up to 1600 deg Celsius, at this temperature the both materials mix chemically and produce calcium silicate. For the production of high and good quality of cement the materials must be in its purest form and composition of uniformity. There are lots of sources of calcium oxide that are limestone, chalk, calcareous moods etc. The OPC is divided into 3 grades that are 33, 43 and 53 grades which means and shows strength after 28 days. The composition of cement is not shown as 100% because of presence of some impurities. Portland cement is made by grinding and mixing of limestone, chalk, marl etc. and argillaceous I.e. shale or clay in the proportion of 2:1 and other materials which contains silica, alumina, or iron oxide. OPC is the most commonly used cement in different constructions.

B. Aggregates

The maximum volume in concrete is occupied by the aggregates which accounts about 80% of the total volume of concrete. The aggregates present in the concrete have great influence on the properties of the concrete. The aggregates are generally derived from naturally occurring rocks, it's of granular form either its crushed are naturally occurred and also includes sand. Aggregates acts as filler and also gives stability to the structure and it has also a great wear resistance. The aggregates which are used in the concrete must be of good and desirable quality, the aggregates should be strong enough against breaking and should free from unwanted impurities. The rocks which gets fractured easily does not provide good quality aggregates as it provide fines which cause unstability to the concrete. The presence of silt, clay increases water demand in the concrete which in turn cause instability and cause hydration in the concrete.

C. Water

The cleaner water is the best water for making of concrete. Water is important and foremost ingredient in the making of concrete as it is used to mix other ingredients and enhances the workability of the concrete. Water is also used for curing and for the setting and hydration of cement.

D. Waste Paper Sludge Ash

The sludge which is generated from the paper mill as a by-product is the main concern and problem for economy and environment. Each and every year tones of waste paper sludge is generated which causes lots of problems. The waste paper sludge is recycled up to certain limit and it is also used in agriculture and it is also dumped in land and under water which is the serious problem for the environment. The WPSA has a cementitous properties as it contains lime at about 20%. It has also pozzolanic properties. When waste paper is recycled after sometimes it becomes weak and cannot make paper of good quality, and this weak paper is separated and is termed as sludge and after burning is converted into ash and termed as waste paper sludge ash.

E. Working Casting

For the casting of the cubes we have to do oiling and also clean the moulds. The tightening of the moulds is also important before the casting. The weighing of ingredients used for the process were also weighted properly and with accuracy. The ingredients were mixed with hand, firstly the dry mixing was done by providing a centered space and the water of about 80% was added. For the proper mixing and workability rest water have been sprinkled. For each mix 6 cubes and 6 cylinders were casted, cubes for compressive strength at 7 and 28 days and cylinders for split tensile strength at 7 and 28 days. WPSA was used in the moulds with the changing in the percentage of the WPSA in different specimen.

F. Compaction

The moulds were filled with the concrete with the four layers of concrete and the compaction was done by using of tamping rod. Each layer of the concrete was tampered with 25 strokes of round tamping rod , the tamping was done uniformly over the whole surface of the concrete layers upon the completion of tamping the extra material was removed and leveled by the metal trowel.

G. Curing of the Concrete

After the completion of the casting of cubes, curing is most important work for the concrete to prevent the concrete from the loss of moisture to maintain the temperature of the concrete. There are different types of curing techniques which are applying to concrete to reduce the permeability and enhance the durability of the concrete by increasing hydration of the cement in the surface and interior the concrete. Curing is also used to prevent concrete from the hot temperature at the early age of the concrete, where concrete is weak to resist the hot atmosphere. Curing is

applied to concrete for up to 14 days and more . Curing can be done by applying water directly to the concrete or to put wet cloth on the concrete. In the present work curing was done to cubes by immersing the cubes in the curing tank for 7 and 28 days and was kept their till the testing of the block.

V. RESULTS AND DISCUSSION

A. General

In this chapter we will see the results which we have obtained during the work done in the laboratory from the specimen. the materials which have been used are the cement, aggregates and WPSA and concrete hard and fresh.

B. Fresh Concrete Slump Test

The slump value obtained id listed below in the table 1.

Table 1: Slump Tests Results

Mix	Percentage	Slump value
Control	0%	90mm
WPSA	2%	62mm
	4%	57mm
	6%	52mm
	8%	20mm

In the above table 1 shows that the upon increasing the WPSA to concrete the value of the slump decreases.

C. Compaction Factor Test

Table 2 shows the values of the compaction factor.

Table 2: Compaction Factor Results

Mix	Percentage	Compaction factor
Control	0%	0.94
WPSA	2%	0.93
	4%	0.90
	6%	0.85
	8%	0.80

The value 0.94 is the compaction factor of the control concrete. As we go on changing the cement by the waste paper sludge ash, the compaction factor of the decreased gradually from 0.93 to 0.80 upon increasing the WPSA into the concrete.

D. Hardened Concrete

- **Effect of age on compressive strength**

The value of 31N/mm^2 of compressive strength has been obtained after 28 days of M20 concrete. The below table 3 represents the values at 7 days and 28 days of the concrete. The values have been obtained during the working of the concrete in the laboratory.

Table 3: Compressive Strength of Control Concrete in N/Mm^2

Concrete grade	7 days	28 days
M20	21	31

The strength of the concrete increases with the increase to its life, the concrete has maximum strength at the age of 28 days of curing time as after the age of 28 days the concrete gets strong slower than its previous time.

- **Effect of age on split tensile strength of control concrete**

The split tensile strength obtained after the age of 28 days to the M20 concrete is 2.70 N/mm^2. The below mentioned table 4 shows the result of the split tensile strength after the age and curing period of 7 and 28 days. The below results have been achieved during the entire course of work.

Table 4: Split Tensile Strength in N/Mm^2

Grade of concrete	7 days	28 days
M20	1.95	2.70

The value of split tensile strength increases with the increase in the time period of curing, as the time period of curing is up to 28 days up to which the concrete gets faster strength after which rate becomes slower.

- **Compressive strength of WPSA at the age of 28 days**

The addition of 2% and 4% of WPSA to the concrete in place of cement shows the higher compressive strength than the control concrete after the age of 7 days. If we increase the %age of WPSA to the concrete there is decrease in the compressive strength. After the age of 28 days the compressive strength of 2% replacement of cement by WPSA is more than the control mix, and for the 4% replacement of cement the compressive strength is nearly equal to the control mix. After the further replacement the compressive strength decreases.

- **Effect on split tensile strength of concrete containing**

Table 5: Split Tensile Strength

Mix	Percentage Of Cement Replacement	Split Tensile Strength (N/Mm^2)	
		7 Days	28 Days
M20	0%	1.95	2.70
WPSA	2%	2.30	3.10
	4%	2	2.90
	6%	1.80	2.80
	8%	1.70	2

From the above information, upon the replacement of 2% and 4% of cement by WPSA the split tensile strength is more than that of the control mix at the age of 7 days and 28 days. For the 6% replacement of cement the split tensile strength is same that of control mix, and for further replacement the split tensile strength decreases.

VI. COST ANALYSIS

A. Cost Of Material

Cost of cement per kg =Rs. 10.00
Cost of sand per kg =Rs. 2.00
Cost of aggregates =Rs. 1.50
Cost of WPSA per kg =Rs. 0.00
(All the rates are without addition of miscellaneous charges, and may vary from place to place)

Table 6: Material Cost for Normal Concrete 'M^3'

Description	Quantity (kg/m^3)	Cost (Rs. Per kg	Material cost (Rs.)
Cement	372	10.00	3720.00
Waste paper sludge ash	0.00	0.00	0.00
Sand	550	2.00	1100.00
Aggregates	1190	1.50	1785.00
Total cost			**6605**

Table no. 6 shows us the cost of concrete in which there is no replacement of cement by the supplementary cementitious material.

Table 7: Material Cost For 2% Wpsa Replacement Of Cement

Description	Quantity (kg/m^3)	Cost (Rs. Per kg)	Cost of material (Rs.)
Cement	353.5	10	3535
Waste paper Sludge ash	18.5	0.00	0.00
Sand	550	2.00	1100.00
Aggregates	1190	1.50	1785.00
Total			**6420.00**

Table 7 shows us the reduction in the concrete when the cement is replaced by 2% of waste paper sludge ash.

Table 8: Material Cost For 4% Wpsa Replacement of Cement

Description	Quantity (kg/m^3)	Cost (Rs. Per kg)	Cost of material (Rs.)
Cement	335	10	3350
Waste paper sludge ash	37.2	0.00	0.00
Sand	550	2.00	1100.00
Aggregates	1190	1.50	1785.00
Total			**6235.00**

Table 8 shows us the reduction in the cost of concrete when the cement is replaced by the 4% 0f waste paper sludge ash ash.

Table 9: Material Cost For 6% WPSA Replacement of Cement

Description	Quantity (kg/m^3)	Cost (Rs. Per kg)	Cost of material (Rs.)
Cement	316	10.00	3160
Waste paper sludge ash	56	0.00	0.00
Sand	550	2.00	1100
Aggregates	1190	1.50	1785
Total			**6045.00**

Table 9 shows us the cost of concrete in which cement has been replaced by the 6% of waste paper sludge ash.

Table 10: Material Cost For 8% Wpsa Replacement of Cement

Description	Quantity (kg/m^3)	Cost (Rs. Per kg)	Cost of material (Rs.)
Cement	298	10	2980
Waste paper sludge ash	56	0.00	0.00
Sand	550	2.00	1100
Aggregates	1190	1.50	1785
Total			**5865.00**

Table 10 shows us the reduction in the cost of concrete by using the waste paper sludge ash in place of the cement.

- **Reduction in cost for 1 m^3 concrete by the:**

2% replacement of cement by WPSA=Rs. 185.00
4% replacement of cement by WPSA=Rs. 370.00
6% replacement of cement by WPSA=Rs. 560.00
8% replacement of cement by WPSA=Rs. 1020.00

VII. CONCLUSION

A. General

The main and the foremost objective of this experimental work is to make the concrete more economical, by replacing the cement by WPSA and also the focus was on the minimizing the use of cement in order to protect the environment.

- **Strength of the control concrete and the WPSA concrete**
  - With the 4% replacement of cement by WPSA there was 10% increase in the split and tensile strength of the concrete. Upon increase in the %age of WPSA more than 10% the strength shows lesser values than control mix, so we can add only up to 8% of WPSA to M20 concrete as supplementary material.
  - From the results it is clear that we can add up to 8% of WPSA in M20 concrete.
  - From results it is clear we can replace cement by WPSA.
  - Upon the addition of 2% of WPSA to concrete, it shows more compressive strength than control mix.
  - The strength of the concrete at the early stages was less and was increasing with time.
  - It has been found during split tensile strength test, the strength was increasing with the increase in WPSA.
  - The addition of the WPSA to concrete made the concrete economical than control concrete because of easy availability and free of cost material.
  - The use of WPSA in the construction industry will make the environment pollution free and by its use concrete will be made sustainable and sludge ash can be used as source of energy during its burning process. And the problem of disposal has been solved to the paper industry.

VIII. FUTURE SCOPE

We have studied in the work that the waste paper sludge has the cementations properties, during the entire course of we have got some clues where further work can be done:

- The study may be further extended to check the ability of concrete to pumping purpose, because nowadays concrete is needed at heights.
- The waste paper sludge is constructional element and it is mandatory to check such concrete under flexure, shear, torsion and compression.
- Work can be done to check out the characteristic strength of concrete using grinded and controlled burnt WPSA.
- Experimental work can be done under the microscope by checking the chemical properties of the WPSA.
- The further more tests which can be done to the concrete containing WPSA are the ; to check the sulphate attack durability under the water conditions, resistance to penetration of chloride ions, corrosion to steel reinforcement and permeability test.

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