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Partial Replacement of Cement with Waste Paper Sludge Ash

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Abstract: Cement production is one of the sources that emit carbon dioxide, in addition to deforestation and combustion of fossil fuels also leads to ill effects on environment. The global cement industry accounts for 7% of earth's greenhouse gas emission. To enhance the environmental effects associated with cement manufacturing and to constantly deplore natural resources, we need to develop other binders to make the concrete industry sustainable. This work offers the option to use waste paper sludge ash as a partial replacement of cement for new concrete. In this study cement in partially replaced as 5%, 10%, 15% and 20% by waste paper sludge ash in concrete for M25 mix and tested for compressive strength, tensile strength, water absorption and dry density up to the age of 28days and compared it with conventional concrete, based on the results obtained, it is found that waste paper ash may be used as a cement replacement up to 5% by weight and the particle size is less the 90µm to prevent reduction in workability.
Keywords: slump test, Compressive strength, split tensile strength, water absorption test, Waste Paper Sludge Ash Concrete, Workability.

I. INTRODUCTION

Concrete is a champion among the most fundamental structural materials, and its use has been widely expanded around the world, owing to its reasonable cost and readily available constituents, as well as its suitability for a wide range of common construction work.

On the other hand cement industry is one the main producers of CO_2 gas (about 10% of worldwide man-made emission of this gas, out of which 50% is from the chemical process and 40% from burning fuel).One of the best techniques for making the concrete industry more sustainable is to employ waste materials instead of natural resources. Sludge from paper mills is a significant economic and environmental issue for the paper and board sector. There is a massive amount of waste paper sludge all over the planet. Paper sludge accounts for 0.7% of total urban garbage generated in India. The most common recycling and disposal routes for paper sludge ash are landfill disposal, which has a limited scope and is governed by an industry code of practice .paper sludge, is made primarily of cellulose fibers, fillers like calcium carbonate and china clay, and leftover chemicals held together by water. The moisture content can reach up to 40% in most of the cases.

The substance is viscous, sticky and hard to dry and it varies in terms of viscosity and lampness. It has high energy content, making it a viable candidate for the use as an alternative fuel in the production of Portland cement. It is currently used as a substitute fuel. The fly ash produced by incinerating paper sludge at around 800c^o may contain reactive silica and alumina (in the form of matakaolin), as well as lime.

Chemically it contributes to the Portland cement constituents. As a result, paper sludge ash could be used as a component in the production of Portland cement.

The silicon dioxide content of waste paper ash is greater. It has the potential to provide concrete an extra boost of strength. This study will attempt to investigate the design characteristics of the concrete when waste paper is used as a partial replacement for cement, in order to generate environmentally friendly concrete known as green concrete.

II. MATERIAL USED

A. Cement and Aggregate

Khyber ordinary Portland cement of 43 grade confining to IS 8112 was used throughout the work. Fine aggregates used throughout the work comprised of clean river sand with maximum size of 4.75mm conforming to zone II as per IS383-1970 with specific gravity of 2.6. Coarse aggregates used consisted of machine crushed stone angular in shape passing through 20mm IS sieve and retained on 4.75mm IS sieve with specific gravity of 2.7.

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B. Waste Paper Sludge ash (WSA)

Waste paper sludge was obtained from JML waste paper corporation, Pathankot, Punjab, India. It was then sun dried and incinerated so as to convert it into ash. The ash was sieved through 90 micron (90μm) Indian Standard sieve. The specific gravity of waste paper sludge ash was found to be 2.6.Chemical composition of paper sludge ash is presented in TABLE 1.Fig.1 shows waste paper sludge ash, Fig.2 shows sieved paper sludge ash and Fig.3 shows mixing of paper sludge ash with cement.

Figure1. Waste paper sludge ash.

Table. 1. Chemical composition of waste paper sludge ash

ELEMENTS	PERCENTAGE CONTENT
O	15.83
Ca	14.94
Si	60.57
Al	2.06
Mg	3.59
S	1.07
K	0.16
Fe	0.92
Na	0.22

Fig 2: sieving of waste paper sludge ash

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Fig 3. Waste paper sludge ash added to cement for blending

III. EXPERIMENTAL INVESTIGATION

A. Mix Proportion

Following the rules and procedures provided by the Indian Standard Method of Concrete Mix Design (IS 10262 – 1982), a design mix for M-25 grade concrete with water cement ratio 0.45 was developed. Standard specimens were mixed, cast, and tested as part of the project. As shown in table 2 below

Table 2: Mix Proportions

Paper sludge ash(%)	W/C ratio	Water(kg/m^3)	Cement (kg/m^3)	Fine Agg. (kg/m^3)	Paper sludge ash(kg/m^3)	Course Agg. (kg/m^3)	Slump(mm)
0	0.45	191	422	678.80	0.00	1107.6	30
5	0.45	191	400.9	678.80	21.1	1107.6	26
10	0.45	191	379.8	678.80	42.2	1107.6	25
15	0.45	191	358.7	678.80	63.3	1107.6	18
20	0.45	191	337.6	678.80	84.4	1107.6	16

B. Test on Cement

The Vicat's Apparatus was used to perform a consistency test on cement in order to estimate the water-cement ratio.

C. Test on Fresh Concrete

1) The Slump Test using a metallic slump mould were used to assess the workability of all concrete mixes. Slump was defined as the difference in level between the height of the mould and the highest point of the subsided concrete as shown in figure 4 below. The slump tests were carried out in accordance with IS 1199-1959.

Figure 4. slump cone test

D. Tests on Hardened Concrete

Cubes of 150mm x 150mm x 150mm and 150mm x 300mm cylinders were made from each concrete mixture to determine compressive strength as shown in table 3 and splitting tensile strength as shown in table 4.The concrete specimens were cured under normal circumstances according to IS 516-1959 and evaluated at 7, 14 and 28 days to determine compressive strength according to IS 516-1959 and splitting tensile strength according to IS 5816-1999.

Table 3: Compressive Strength Test results for cube specimens of size 150mm x 150mm x 150mm.

S.NO.	Paper sludge ash (%age)	Avg. load @7 days(KN)	Avg. load @14 days(KN)	Avg. load @28 days(KN)	Avg. compressive strength@7days(N/mm^2)	Avg. compressive strength@14days(N/mm^2)	Avg. compressive strength@28days(N/mm^2)
1	0	480	533	633	21.79	22.36	28.51
2	5	513	590	660	24.67	25.70	32.50
3	10	450	530	595	21.05	22.14	26.54
4	15	400	480	556	19.60	20.74	24.09
5	20	340	310	490	17.65	18.82	22.67

Table 4: Splitting Tensile Strength Test results of 150mm x 300mm cylinders

S.NO.	Paper sludge ash (%age)	Avg. load @7 days(KN)	Avg. load @14 days(KN)	Avg. load @28 days(KN)	Avg. split tensile strength@7days(N/mm^2)	Avg. split tensile strength@14days(N/mm^2)	Avg. split tensile strength@28days(N/mm^2)
1	0	150	160	182	2.260	2.273	2.532
2	5	157	167	195	2.353	2.380	2.616
3	10	153	155	175	2.146	2.226	2.463
4	15	145	147	162	2.121	2.193	2.373
5	20	125	132	149	1.866	1.933	2.220

Figure 5. Compressive strength of cube using CTM

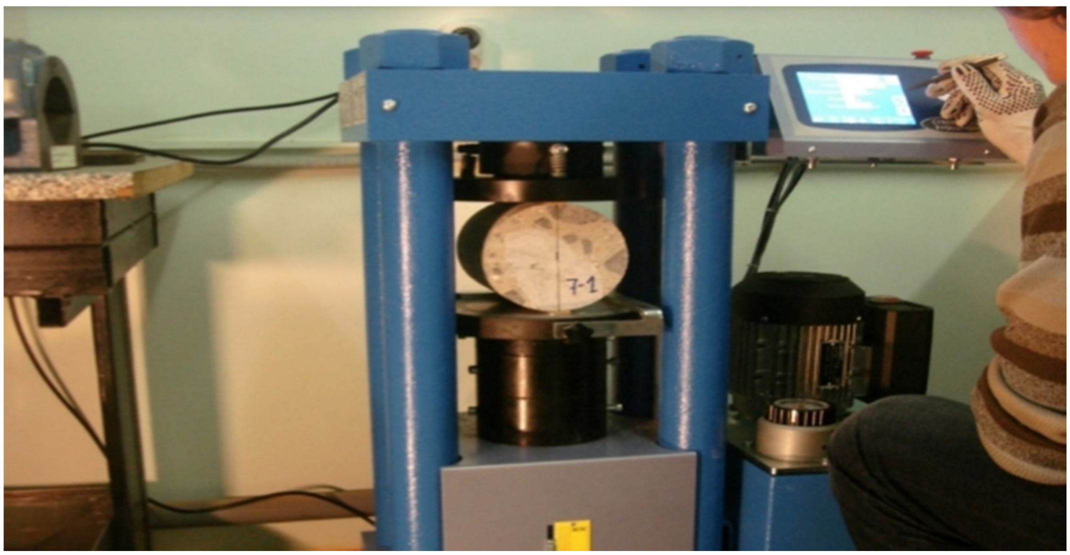

Figure 6. split tensile strength test of cylenders

E. Water Absorption Test

At 28 days of age, the average dry weight of cube specimens after withdrawing from moulds was measured, the average weight of cube specimens after immersion in water for curing is shown in Table 5 The percentage of water absorption was calculated for each concrete specimen and provided an indirect indicator of durability.

Table 5: Water Absorption Test results for cube specimens of size 150mm x 150mm x 150mm

S.NO.	Paper sludge ash (%age)	Dry weight of cube (gm)	Wet weight of cube (gm)	Water absorbed (gm)	Percentage water absorbed
1	0	8380	8476	98	1.17
2	5	8354	8458	104	1.24
3	10	8220	8335	115	1.39
4	15	8112	8238	126	1.55
5	20	7996	8133	137	1.71

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IV. RESULTS AND DISCUSSION

A. Fresh Concrete

The slump values for all of the mixes are shown in table 2 . As the ash concentration of waste paper sludge increased, the slump value reduced. When compared to cement, waste paper sludge ash particles absorbed more water, lowering the workability of the concrete mix. The concrete mixture incorporating 5% waste paper sludge ash in place of cement had the greatest slump. Figure 7 depicts the slump fluctuation with waste paper sludge ash content.

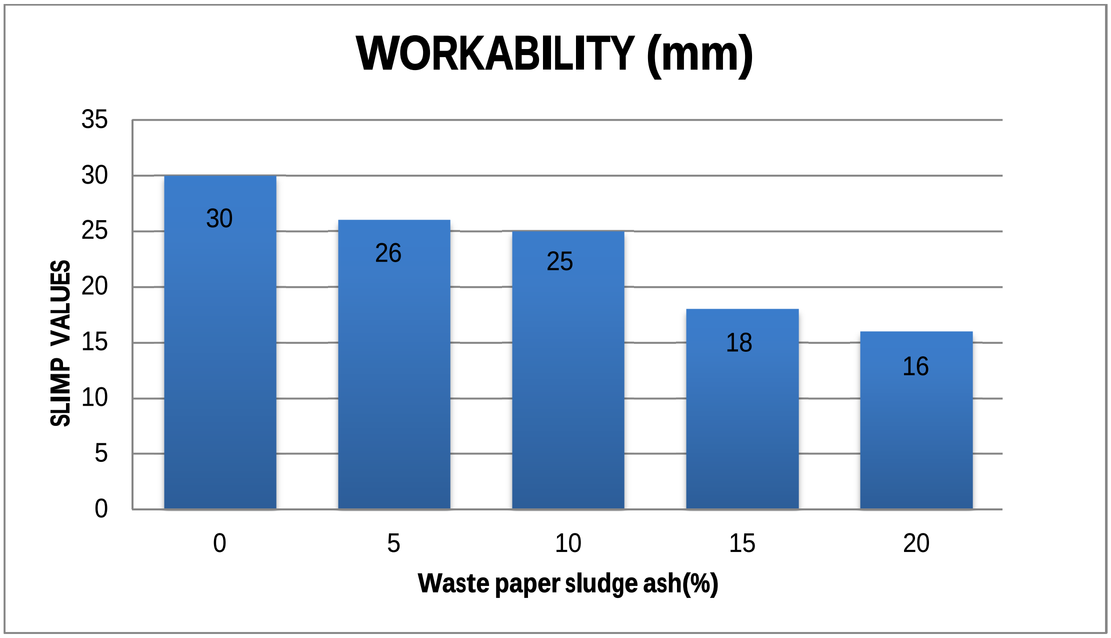

Fig.7: Slump Value (mm)

B. Hardened Concrete

The compressive strength tests and splitting tensile strength tests are shown in table 4 and 5 respectively , compressive strength and splitting tensile strength tests were performed at the age of 7,14 and 28 days of curing. Compressive strength increased at 5% cement substitution with waste paper sludge ash and thereafter decreased. At 28 days, the maximum compressive strength recorded was 13.90% higher than that of the reference mix, equivalent to a concrete mix using 0% waste paper sludge ash in place of cement. The compressive strength of concrete mixes containing 10%, 15%, and 20% waste paper sludge ash was found to be smaller than that of the reference mix. At 5% cement substitution, the splitting tensile strength was found to be greater than that of the reference mix. The tensile strength of splitting reduced as the ash concentration of waste paper sludge increased. Figures 8, 9 and 10 show the compressive strength of all mixes after 7,14 and 28 days. Figures 11,12and 13 show the splitting tensile strength of all mixes after 7,14 and 28days respectively.

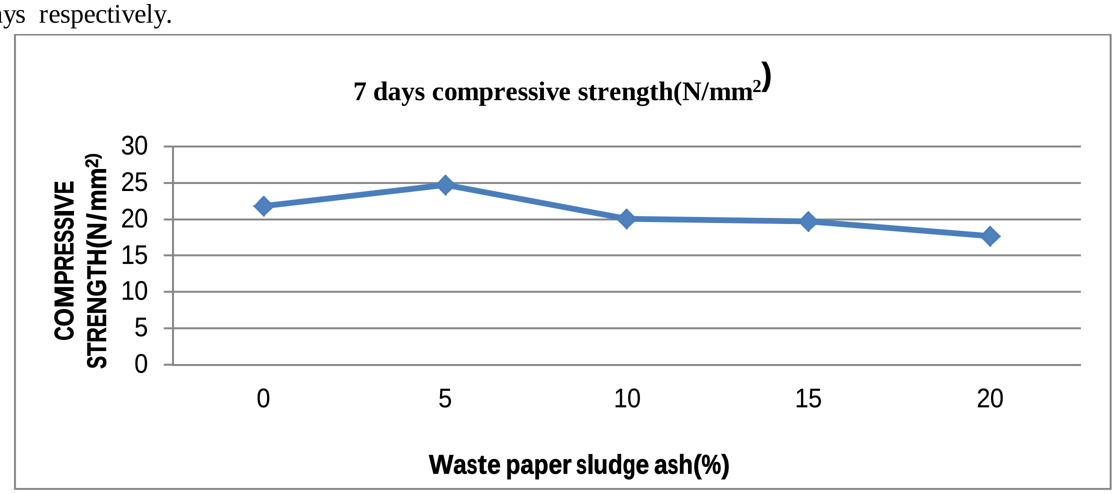

Figure 8: Variation of Compressive Strength @ 7days age

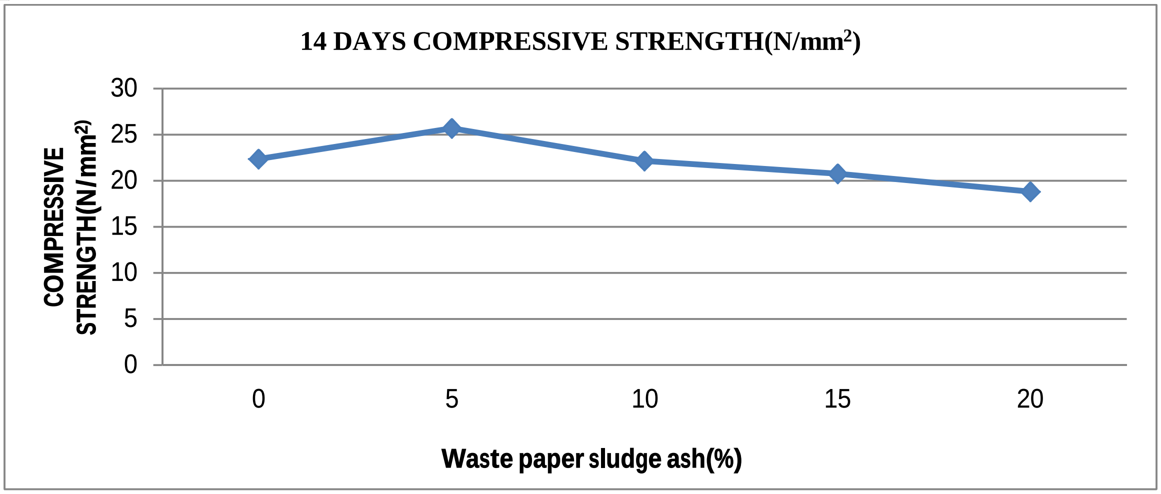

Figure 9: Variation of Compressive Strength @ 14days age

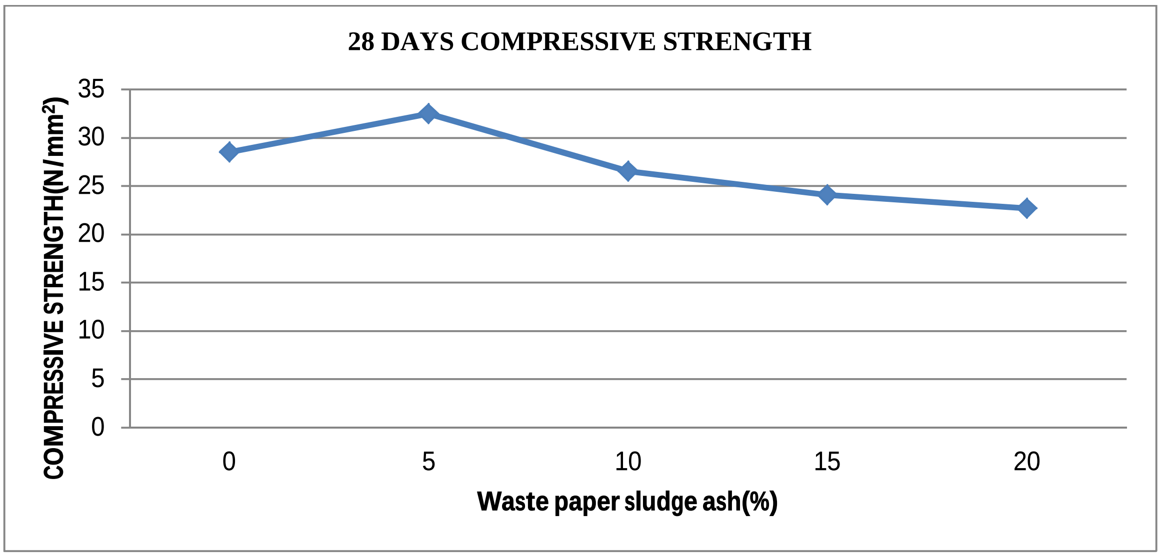

Figure 10: Variation of Compressive Strength @ 28days age

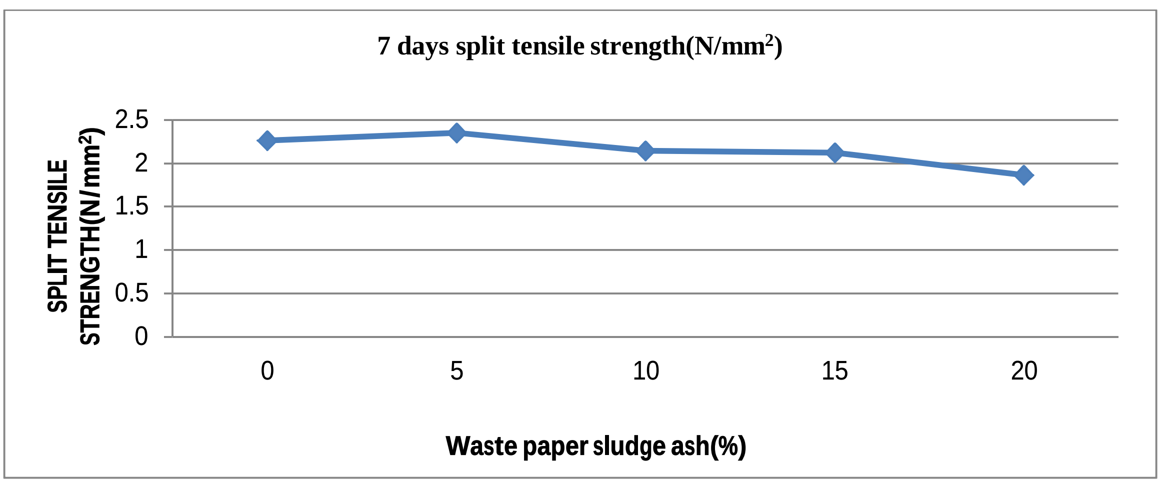

Figure 11: Variation of split tensile Strength @ 7days age

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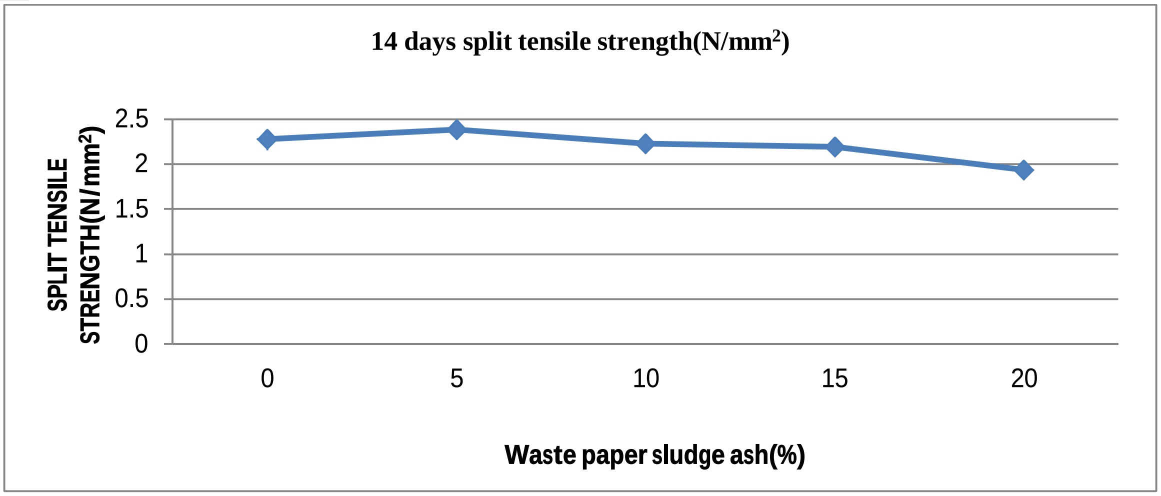

Figure 12: Variation of split tensile Strength @ 14days age

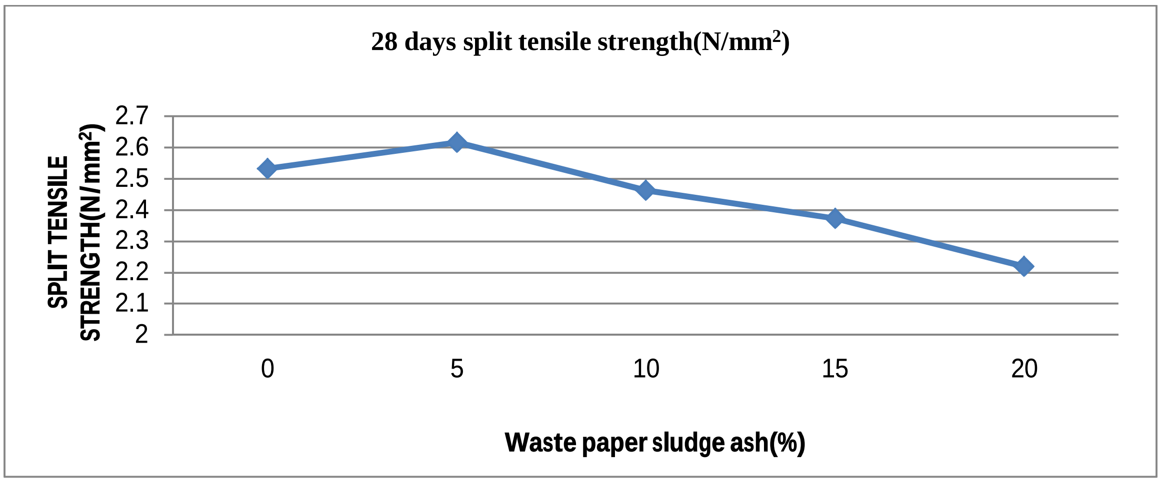

Figure 13: Variation of split tensile Strength @ 28days age

C. Water Absorption

Water absorption tests were performed on all mixes, and the percentage of water absorption was calculated. The percentage water absorption rise as the ash content of waste paper sludge increased. The concrete mix with 5% waste paper sludge ash content had the lowest water absorption value. The percentage water absorption for all mixes is shown in table 5 and Figure.14.

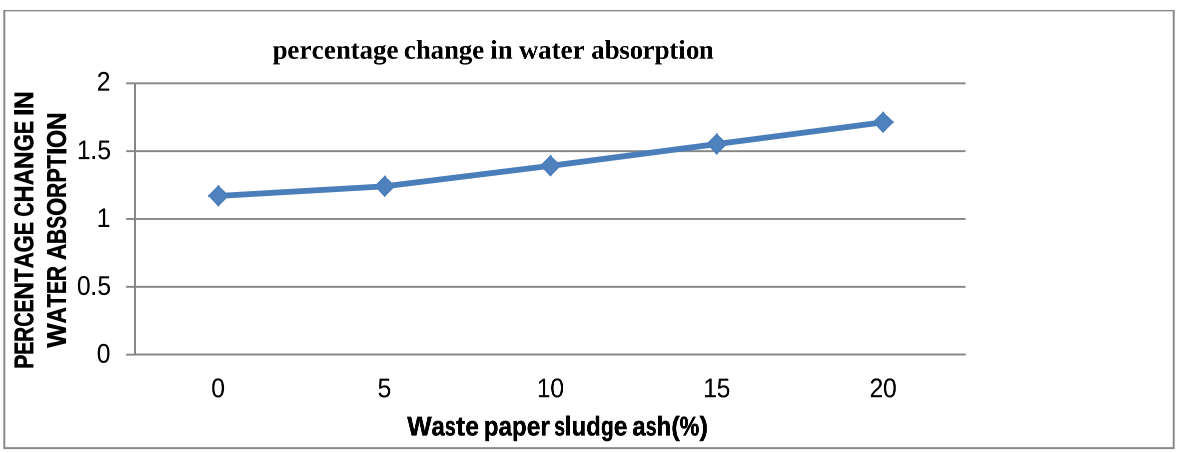

Figure 14: Percentage of water absorbed

V. CONCLUSION

This research was conducted to understand the effect caused due to the addition of waste paper sludge ash as the partial replacement of cement. The fresh concrete property like slump test and the hardened properties of concrete i.e., Compressive Strength, Split Tensile Strength & water absorption tests were conducted very carefully at different ages.

The different observations considering the test results are as following:

1) The workability of concrete after the addition of waste paper sludge ash showed a decrease in the slump value.
2) From the work out, it was found that increase in the quantity of waste paper sludge ash content will reduce the workability and distracts the uniformity of mixes.
3) The peak compressive strength of concrete at 28 days was found to be 13.95% higher for M_1 mix in which cement was partially replaced by waste paper sludge ash than the nominal concrete.
4) The concrete shows increase in compressive strength on adding 5% of waste paper sludge ash by weight in place of cement. From work out it is found that the compressive strength of concrete gets decreased on further addition of waste paper sludge ash.
5) The average weight of concrete decrease on adding waste paper sludge ash, with increase in waste paper sludge ash content, the average weight decrease by 4.58% for M4. In which cement is replaced by 20% of waste paper sludge ash by weight of cement. Thus making the waste paper sludge ash concrete as the light weight concrete.
6) The split tensile strength of concrete was found to be higher that the plain concrete and a highest strength of 13.00% were recorded for M_1 mix (on 5% addition of waste paper sludge ash in place of cement) at 28 days
7) Use of waste paper sludge ash in concrete can prove to be economical as it is non useful waste and free of cost.
8) Use of waste paper sludge ash in concrete will eradicate the disposal problem of waste paper sludge ash, reduce emission of harmful pollutants by cement manufacturing industry into our environment and thus prove to be environment friendly, paving way of greener concrete.
9) Use of waste paper sludge ash in concrete will preserve natural resources that are used for cement manufacturing and thus make concrete construction industry sustainable and waste paper sludge can be used as fuel before using its ash in concrete for partial replacement and also the disposal problem for paper industries for this waste material is fully solved.

V. ACKNOWLEDGEMENT

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