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Study of Concrete Involving Use of Waste Paper Sludge Ash as Partial Replacement of Cement

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List of Figures and Tables:

Abstract: - Cement manufacturing industry is one of the carbon dioxide emitting sources besides deforestation and burning of fossil fuels and concrete industry is one of the largest consumers of natural virgin materials. The global cement industry contributes about 7% of greenhouse gas emission to the earth's atmosphere. In order to address environmental effects associated with cement manufacturing and constantly depleting natural resources, there is a need to develop alternative binders to make concrete industry sustainable. This work examines the possibility of using waste paper sludge ash as partial replacement of cement for new concrete. In this study waste paper sludge ash was partially replaced as 5%, 10%, 15% and 20% in place of cement in concrete for M-25 mix and tested for its compressive strength, tensile strength, water absorption and dry density up to 28 days of age and compared with conventional concrete. From the results obtained, it is found that Waste Paper Sludge Ash can be used as cement replacement up to 5% by weight and particle size less than 90µm to prevent decrease in workability. Further waste paper sludge has very high calorific value and could be used as a fuel before using its ash as partial cement replacement.

Keywords: - *Compressive strength, Durability, split tensile strength, Waste Paper Sludge Ash Concrete, Workability*

I. INTRODUCTION

In order to make concrete industry sustainable, the use of waste materials in place of natural resources is one of the best approaches. Paper mill sludge is a major economic and environmental problem for the paper and board industry. An enormous quantity of waste paper sludge is generated all around the world. In India, 0.7% of total urban waste generated comprises of paper sludge. UK produces over 1.5 million tons of waste paper sludge annually. Paper mill sludge is a major economic and environmental problem for the paper and board industry. The material is a by-product of the de-inking and re-pulping of paper. The main recycling and disposal routes for paper sludge are land-spreading as agricultural fertilizer, incineration in CHP plants at the paper mill, producing paper sludge ash, or disposal to landfill. The scope for landfill spreading is limited and is covered by an industry code of practice. In functional terms, paper sludge consists of cellulose fibers, fillers such as calcium carbonate and china clay and residual chemicals bound up with water. The moisture content is typically up to 40%. The material is viscous, sticky and hard to dry and can vary in viscosity and lumpiness. It has an energy content that makes it a useful candidate as an alternative fuel for the manufacture of Portland cement. Paper sludge is currently in use as an alternative fuel. It is classified as Class 2 (liquid alternative fuels) in the Cembureau classification of alternative fuels. After incinerating paper sludge at approximately 800 ^{0}C, the

resultant fly ash may contain reactive silica and alumina (in the form of metakaolin) as well as lime (CaO) which contributes chemically to the Portland cement ingredients. Paper sludge ash is therefore potentially suitable as an ingredient in:
- the cement kiln feed, contributing calcium, silica and alumina.
- the manufacture of blended cements.

This research will summarize the behavior of concrete with the waste paper sludge ash by replacement of cement in the range of 5%, 10%, 15% and 20% which may help to reduce the disposal problem of sludge and enhance the properties of concrete. As wastepaper sludge ash contains higher percentage of silicon dioxide SiO_2, it may provide extra strength to concrete. This project will try to study the design parameters of concrete on inclusion of waste paper as partial replacement of cement.

II. MATERIALS USED

2.1. Cement and Aggregates

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.

2.2. 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.

Fig.1: Waste Paper Sludge Ash

Table 1. Chemical composition of waste paper sludge ash

Element	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

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

III. EXPERIMENTAL INVESTIGATION

3.1. Mix Proportion

The concrete mix design was proposed by using IS 10262. The grade of concrete used was M-25 with water to cement ratio of 0.45. The mixture proportions used in laboratory for experimentation are shown in TABLE 2.

Table 2: Mix Proportions

Paper Sludge Ash %	w/c ratio	Water (Kg/m^3)	Cement (Kg/m^3)	Fine Aggregate (Kg/m^3)	Paper Sludge Ash (Kg/m^3)	Coarse Aggregate (Kg/m^3)	Slump (mm)
0	0.45	191.6	425.80	543.5	0.00	1199.36	25
5	0.45	191.6	404.51	543.5	21.29	1199.36	24
10	0.45	191.6	383.22	543.5	42.58	1199.36	20
15	0.45	191.6	361.93	543.5	63.87	1199.36	16
20	0.45	191.6	340.64	543.5	85.16	1199.36	13

3.2. Test on Cement

Consistency Test was performed on cement using Vicat's Apparatus so as to determine the water-cement ratio.

3.3. Test on Fresh Concrete

3.2.1. Slump Test The workability of all concrete mixtures was determined through slump test utilizing a metallic slump mould. The difference in level between the height of mould and that of highest point of the subsided concrete was measured (Fig.3) and reported as slump. The slump tests were performed according to IS 1199-1959.

Fig.4: Slump cone being removed slowly.

3.4. Tests on hardened concrete

From each concrete mixture, cubes of size 150mm x 150mm x 150mm and 150mm x 300mm cylinders have been casted for the determination of compressive strength (Table 3) and splitting tensile strength (Table 4) respectively (Fig.4 & 5). The concrete specimens were cured under normal conditions as per IS 516-1959 and were tested at 7 days and 28days for determining compressive strength as per IS 516-1959 and splitting tensile strength as per IS 5816-1999 .

Fig.5: Compressive strength test of cube using CTM

Fig. 6. Cylinder specimen failing in splitting cylinder test

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

S. No.	Paper Sludge Ash %	Avg. load @ 7days (KN)	Avg. Load @ 28 days(KN)	Avg. Compressive Strength @7 days(N/mm^2)	Avg. Compressive Strength @28 days(N/mm^2)
1	0	483	633	21.48	28.07
2	5%	513	657	**23.628**	**32.343**
3	10%	453	593	20.15	26.29
4	15%	403	557	17.92	24.74
5	20%	345	498	15.14	22.147

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

S. No.	Paper Sludge Ash %	Avg. load @ 7days (KN)	Avg. Load @ 28 days(KN)	Avg. Split Tensile Strength @7 days(N/mm^2)	Avg. Split Tensile Strength @28 days(N/mm^2)
1	0	150	180	2.122	2.546
2	5%	157	190	**2.225**	**2.688**
3	10%	153	177	2.157	2.510
4	15%	145	165	2.051	2.334
5	20%	125	150	1.768	2.122

3.5. Water absorption test

The average dry weight of cube specimens after removing from moulds was measured and the average weight of cube specimens after submerging in water for curing was measured at 28 days of age (Table 5). The percentage of water absorption was measured for each concrete specimen and it gave indirect measure of durability.

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

S. No.	Paper Sludge Ash %	Dry weight of cube (gm)	Wet weight of cube (gm)	Water absorbed (gm)	Percentage water absorption
1	0	8382	8280	98	1.17%
2	5%	8352	8456	104	1.245%
3	10%	8225	8340	115	1.398%
4	15%	8115	8241	126	1.552%
5	20%	7998	8135	137	1.713%

3.6. Light weight character

The average dry weight of concrete cube specimens containing 5%, 10%, 15% and 20% waste paper sludge ash in place of cement by weight was compared with average dry weight of normal M-25 concrete cube specimens and the percentage decrease in dry weight was measured (Table 6).

Table 6: Dry Weight Density results for cube specimens of size 150mm x 150mm x 150mm

S. No.	Paper Sludge Ash %	Avg. Dry weight of cube (gm)	Avg. dry density of cube (KN/m^3)	Percentage change in weight as compared to reference (%)
1	0	8382	24.83	0%
2	5%	8352	24.75	- 0.358%
3	10%	8225	24.37	- 1.870%
4	15%	8115	24.04	- 3.185%
5	20%	7998	23.70	- 4.580%

IV. RESULTS AND DISCUSSION

4.1. Fresh concrete

The slump values of all the mixtures are represented in TABLE 2. The slump decreased with the increase in waste paper sludge ash content. Waste paper sludge ash particles absorbed more water as compared to cement and thus decreasing the workability of concrete mix. Slump was maximum for the concrete mixture containing 5% waste paper sludge ash in place of cement. The variation of slump with waste paper sludge ash content is depicted in Fig. 7.

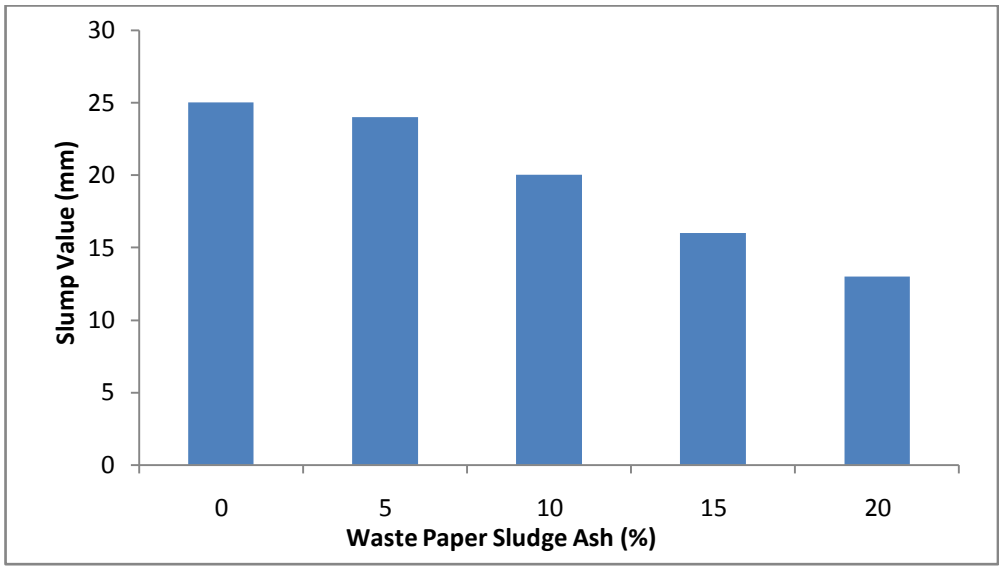


Fig.7: Slump Value (mm)

4.2. Hardened concrete

The compressive strength tests and splitting tensile strength tests are presented in TABLES 3 & 4 respectively. Compressive strength tests and splitting tensile strength tests were carried out at 7 and 28 days. An increase in compressive strength was observed at 5% replacement of cement by waste paper sludge ash and there after decreasing. The maximum compressive strength measured was 15% more than that of reference mix at 28 days corresponding to concrete mix containing 0% waste paper sludge ash in place of cement. Compressive strength for concrete mix with 10%, 15% and 20% waste paper sludge ash content was found to be less than that of reference mix. Splitting tensile strength was found to be more than that for reference mix at 5% cement replacement. Splitting tensile strength decreased with increasing waste paper sludge ash content. Fig. 8 and 9 present compressive strength of all mixtures at 7 and 28 days respectively. Fig. 10 and 11 present splitting tensile strength of all mixtures at 7 and 28 days respectively.

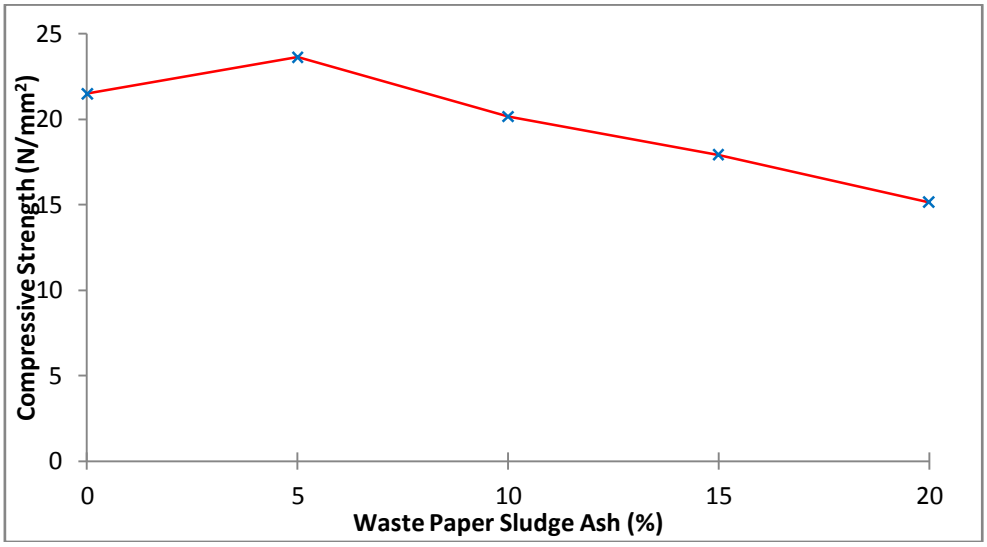


Fig.8: Variation of Compressive Strength @ 7days age

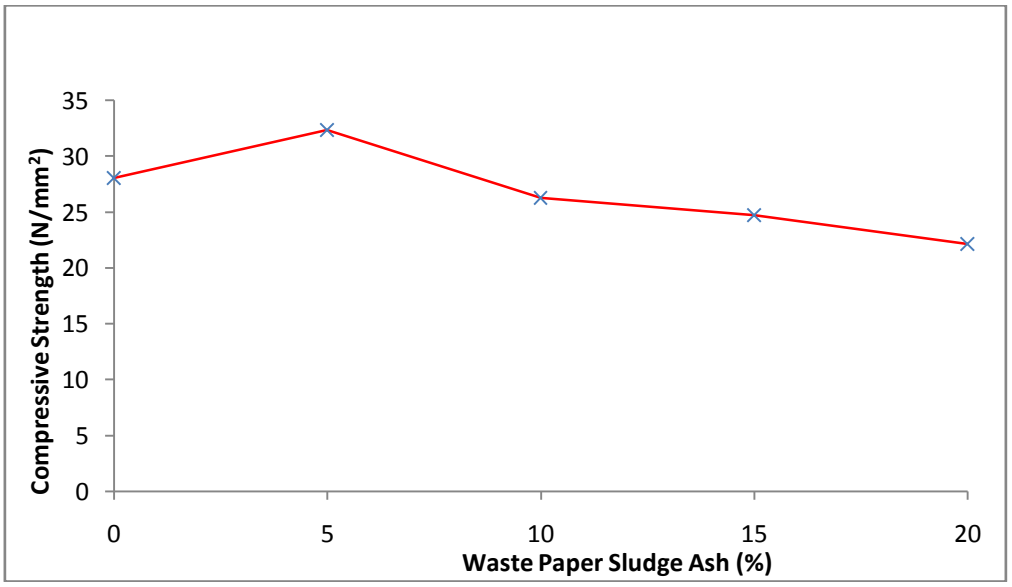
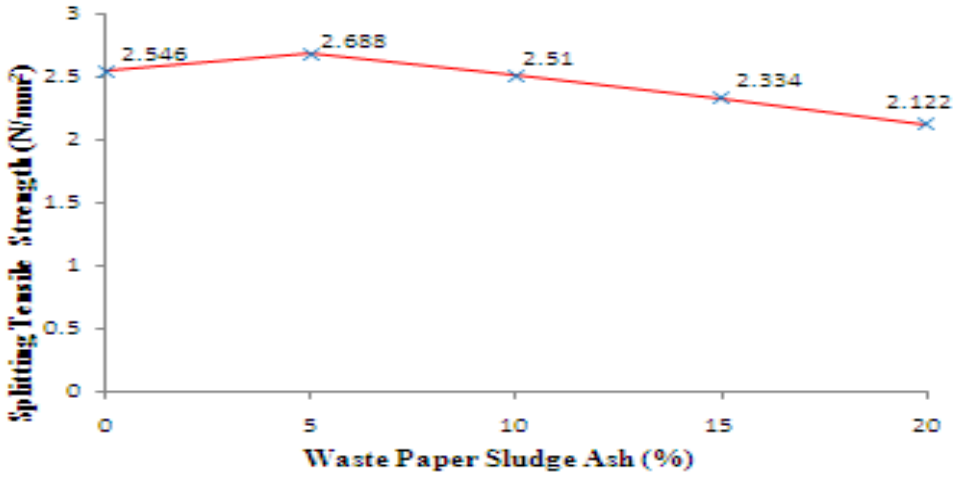


Fig.9: Variation of Compressive Strength @28days age

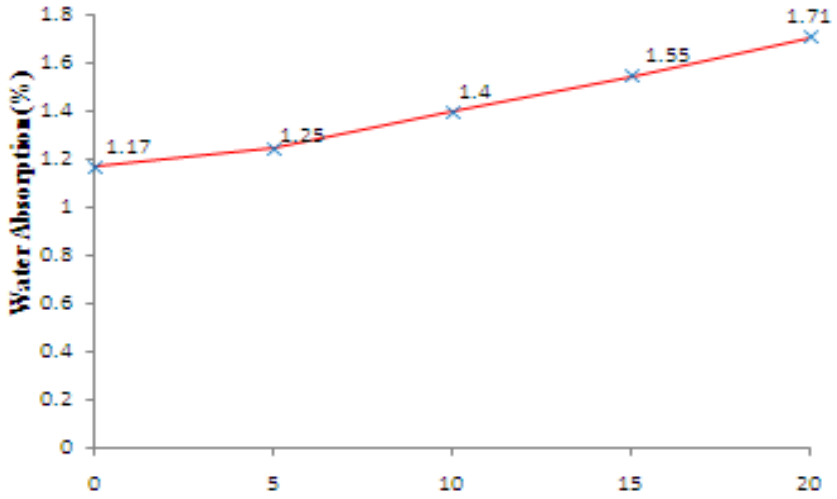
Fig.10: 7 days Splitting Tensile Strength (N/mm²)



4.3. Water absorption

Water absorption test was carried out for all mixtures and percentage water absorption was measured. The percentage water absorption increased with increase in waste paper sludge ash content. The lowest value of water absorption was found for concrete mix with 5% waste paper sludge ash content. TABLE 5 & Fig.12 depicts the percentage water absorption for all mixtures.

Fig.11: 28 days Splitting Tensile Strength (N/mm^2)



4.4. Light weight character

Average dry weight of cube specimens of each mixture as compared to reference mix was studied and it was observed that density decreased with increase in waste paper sludge ash content. The results showed 4.58% reduction in dry weight of concrete cube specimens for concrete mix with 20% waste paper sludge ash content as compared to reference mix.This reduction in density can be attributed to lesser specific gravity of waste paper sludge ash as compared to cement. Thus, waste paper sludge ash concrete is light weight in nature. TABLE 6 & Fig. 13 depicts the value of dry density and percentage change in dry weight with respect to reference mix.

Fig.12: Water Absorbed (%)

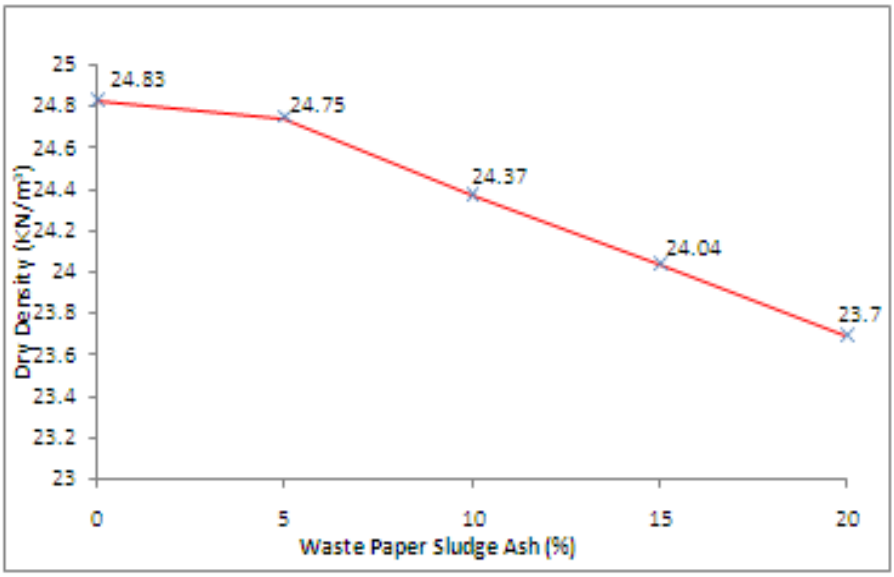
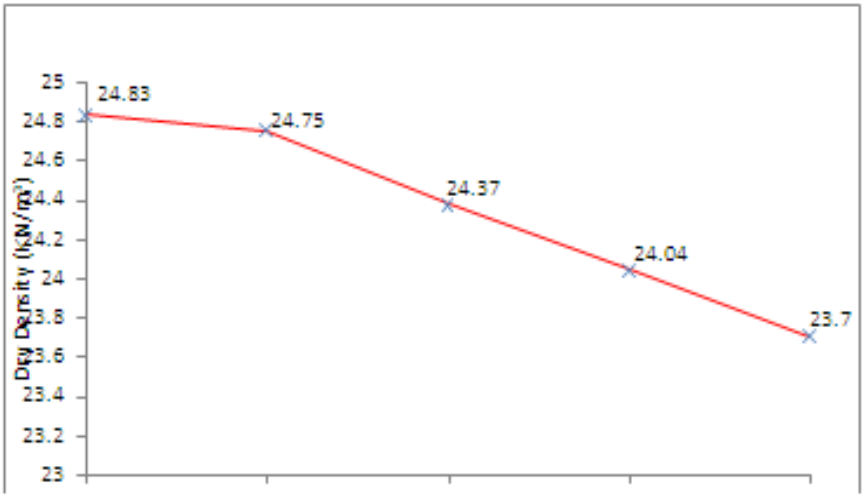


Fig.13: Dry Density of Cube (KN/m³)



V. CONCLUSION

On the basis of results obtained, following conclusions can be drawn:

1. 5% replacement of cement by waste paper sludge ash showed 10% increase in compressive strength at 7 days and 15% increase in compressive strength at 28 days.
2. Cement in concrete can be replaced by waste paper sludge ash up to 5% by weight showing 15% increase in compressive strength at 28 days.
3. With increase in waste paper sludge ash content, percentage water absorption increases.
4. With increase in waste paper sludge ash content, average weight decreases by 4.58% for mixture with 20% waste paper sludge ash content thus making waste paper sludge ash concrete light weight.
5. Workability of concrete mix decreases with increase in waste paper sludge ash content.
6. Splitting tensile strength decreases with increase in waste paper sludge ash content and is more than reference concrete at 5% replacement.
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 manufacture industry into our environment and thus prove to be environment friendly, paving way for greener concrete.
9. Use of waste paper sludge ash in concrete will preserve natural resources that are used for cement manufacture and thus make concrete construction industry sustainable and waste paper sludge can be used as fuel before using its ash in concrete for partial cement replacement and also the disposal problem for paper industries for this waste material is fully solved.

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