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Study of Waste Paper Sludge Ash Concrete for Partially Replaced for M25 and M40 Grade of Concrete

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Abstract: The use of waste paper sludge ash in concrete formulations was investigated as an alternative to landfill disposal. In this paper represents the optimum use of the waste paper sludge ash with the concrete mixture cement has been replaced by waste paper sludge ash in the range of 0%, 5%, 10%, 15% and 20% by the weight for M-25 and M-40 grade of mix with water binder ratio various from 0.5 and 0.40. The concrete mixtures were produced and compared in terms of fresh and hardened properties with the conventional concrete. The concrete specimen was tested in test as compression test, split tensile test and flexural strength test of concrete at 7, 28, and 56 days. The water absorption, dry density test of concrete at 28 days' age of concrete and compared with the conventional concrete. It can be concluded that the optimum percentage of waste paper sludge ash as a result, the compressive, splitting tensile and flexural strength increased up to 10% 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: Waste Paper Sludge Ash, Compressive Strength, Split Tensile Strength, Flexural Strength and Durability Test.

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 [1]. Paper making industries generally produces a large amount of solid waste. Paper fibers can be recycled only a limited number of time before they become too short or week to make high quality paper. From paper manufacturing process three types of sludge are obtained namely Hypo sludge, ETP sludge and De-inking sludge. Each Indian mill produces an average 40 over-dry tones of sludge per day [2].

About 300 kg of sludge is produced for each tone of recycled paper. This is a relatively large volume of sludge produced each day that makes making landfill uneconomical as paper mill sludge is bulky [5]. 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. It is classified as class 2 in the cembureau classification of alternative fuels. After incinerating paper sludge at approximately 800º C, the resultant fly ash may contain reactive silica and alumina as well as lime 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, and the manufacture of blended cements [3].

In this study will summarize the utilization of waste paper sludge ash as partial replacement of cement in the range of 5%, 10%, 15% & 20% by weight for M25 and M40 mix which may help to decrease the disposal problem of waste paper sludge and improve the properties of concrete. Concrete mix is compared in terms of strength with conventional concrete. The concrete mix specimen is compared with compression test, split tensile test, flexural test, water absorption and density test. This research will try to investigate the design parameters of waste paper sludge ash as partial replacement of cement concrete.

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1.1 Chemical reactions involved in partially replaced in concrete

1. Primary Hydration

Cement + Water → C-S-H (gel) + Ca $(OH)_2$

2. Secondary Hydration

Here Hypo sludge act as Pozzolana.

Ca $(OH)_2$ + Pozzolana→ C-S-H (gel)

Increase in amount of C-S-H gel increase the compressive strength but only up to a certain extent [4].

II. LITERATURE REVIEW

Based on several experimentalstudies have been carried out on the concrete by the partial replacement of cement with paper sludge ash. Strength parameter such as compressive strength, tensile strength, flexural strength and durability test were studied and obtained test results will be compared with the conventional concrete. The main aim of this section is to present an overview of research work carried out by various researchers in the field of waste paper sludge ash. Jaisurya P et al (2018) reported the results of a compressive strength, split tensile strength and flexural strength, the value range should be increase for 5% replacement of cement using paper sludge ash on 28 days' test compare to conventional concrete. In (2013) 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. With the addition of increase in waste paper sludge ash content, the percentage of water absorption increases. Was concluded [6] Considering the strength criteria, the replacement of cement by paper sludge ash is feasible. Therefore, we can conclude that waste paper sludge ash can be used as partial replacement of cement up to 10%. The inclusion of 50% WPSA can gain favorable strength mortar at 16.4 MPa. Meanwhile 70% and 100% replacement to achieve lower strength at 12.5 MPa to 7.7 MPa respectively and 100% WPSA mix indicates high water absorption about 27.05% and reduce the compressive strength when compared to plain mortar [7]. AfshaNigr et al (2020), reported that M25 grade of concrete the results of a compressive strength increase for 10%, split tensile strength and flexural strength, the value range should be increase for 10 to 15% replacement of cement using paper sludge ash on 28 days' test compare to conventional concrete.

III. METHODOLOGY

A. Selection of Materials

In this study various materials like Cement, Aggregate, Water and Waste paper sludge ash were used and their properties are examined based on IS codes [8, 9].

a) Cement:

Ordinary Portland cement of Ultratech brand 53 grade confirming to IS 12269- 1987(9) was used in this study, with specific gravity 3.14.

b) Fine Aggregate (M- sand)

Those fraction from 4.75 mm to 150 microns are termed as fine aggregate. In this investigation locally available M-sand is used as a fine aggregate, confirming to grading zone II as per IS 383-1970, with specific gravity 2.7

c) Coarse Aggregate

Coarse aggregate includes natural aggregates. Locally available crushed stone of 20 mm down sizes confirming to IS: 383 have been used as coarse aggregate, with specific gravity 2.65.

d) Water

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Here Potable water was used for the mixing and curing.

e) Admixture

Conplast SP430 is used for high performance water reducing and super plasticizing admixture.

f) Waste Paper Sludge Ash (WPSA)

Waste paper sludge was obtained from South India Paper Mills Pvt. Ltd. Tandavapura, Mysuru, Karnataka, India. It was sun dried and incinerated at 700° C for 2 hours converted into ash. The ash was sieved through 90 microns' Indian standard sieve. The specific gravity of waste paper sludge ash was found to be 2.45. the chemical composition of paper sludge ash is presented in Table 3.1, Fig.3.1 shows waste paper sludge, Fig.3.2 shows sieved paper sludge ash.

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Fig.3.1: Waste Paper Sludge

Fig.3.2: Sieved Paper Sludge Ash

Table 3.1: Chemical composition of waste paper sludge ash

Elements	Weight %	Atom %
C k	37.37	48.93
O k	43.10	42.36
Al k	2.81	1.64
Si k	4.22	2.36
S k	0.48	0.24
Cl k	0.50	0.22
Ca k	9.18	3.60
Fe k	2.33	0.66
Total	100.00	100.00

B. Mix Design

The process of selecting a suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required strength, durability, and workability as economically as possible is termed the concrete mix design. M25 and M40 concrete mix is prepared for this study, total 10 mix of concrete is prepared 5 of each containing waste paper sludge ash was in different percentage. Mix design of these mix is done as per IS 10262: 2009 specifications, Mix designation of concrete is presented in Table 3.2

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Table 3.2: Mix Proportions of M-25 and M-40 concrete

Sl. No	Concrete Grade	Mix Name	WPSA (%)	WPSA (Kg)	W/C ratio	Cement (Kg/m^3)	F A (Kg/m^3)	C A (Kg/m^3)	Water (Kg/m^3)	Slump (mm)
1	M-25	A1-M25	0	-	0.5	334.11	852	1067.6	167	97
2		B1-M25	5	16.70	0.5	317.4	852	1067.6	167	95
3		C1-M25	10	33.41	0.5	300.69	852	1067.6	167	92
4		D1-M25	15	50.11	0.5	283.99	852	1067.6	167	89
5		E1-M25	20	66.82	0.5	267.28	852	1067.6	167	85
6	M-40	A2-M40	0	-	0.4	440	761.88	1027.26	177.3	94
7		B2-M40	5	22	0.4	418	761.88	1027.26	177.3	89
8		C2-M40	10	44	0.4	396	761.88	1027.26	177.3	85
9		D2-M40	15	66	0.4	374	761.88	1027.26	177.3	81
10		E2-M40	20	88	0.4	352	761.88	1027.26	177.3	78

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C. Casting and Curing

To decide the compressive strength of a waste paper sludge ash concrete, cubes of 150mm*150mm*150mm size are used and 100mm*100mm*500mm beam is casted for flexural strength test and 150mm*300mm cylinder casted for split tensile strengthandCasted samples were placed in curing tank for curing period of 7 days, 28 days and 56 days.

Fig.3.3: Casted Concrete Specimens **Fig.3.4: Setup of Water Curing**

IV. RESULTS AND DISCUSSIONS

A. Test on Fresh Concrete

The slump cone test using a metallic mould were used to an assess the workability of all the concrete mixes. The workability was defined as the difference in level between the height of the mould and the highest point of the subsided concrete as shown in table 3.2. The increase in waste paper sludge ash noticed that decrease in slump value and Fig 4.1 shows the variation of slump values with different concrete mixes.

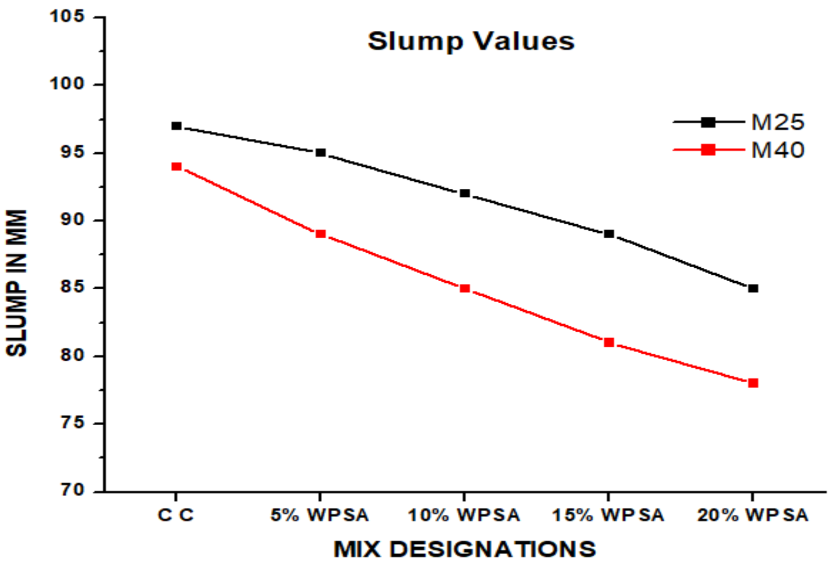

Fig. 4.1: Variation of Slump test result of M25 and M40 concrete

Slump of the concrete goes on decreasing when waste paper sludge ash is introduced in concrete as partial replacement of cement in concrete, waste paper sludge ash particles absorbed more water as compared to cement and thus decreasing the workability of concrete mix.

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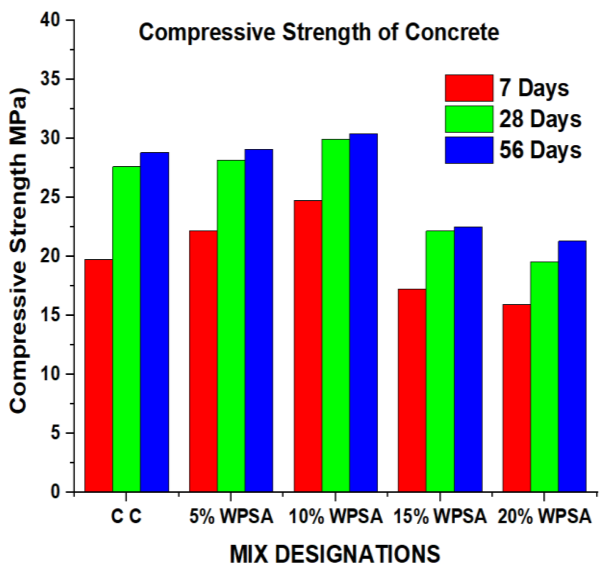
A1-M25 with 0% paper sludge ash gives 97 mm slump where as in B1-M25 with 5% replacement gives 95 mm slump, which goes on decreasing to attain 85 mm slump at 20 % replacement of E1-M25, similarly A2-M40 with 0% paper sludge ash gives 94 mm slump where as in B2-M40 with 5% replacement gives 89 mm slump, which goes on decreasing to attain 78 mm slump at 20 % replacement.

B. Compressive Strength of concrete with varying waste paper sludge ash

The compression testing of concrete, 150 mm cubes were used, the compressive strength of concrete for different percentages of waste paper sludge ash replacement is presented in Table 4.1, Figure 4.2, can be observed that there is an increase in compressive strength up to 10% replacement of waste paper sludge ash and beyond that increasing percentage of waste paper sludge ash decrease the compressive strength.

Table 4.1: Compressive strength of concrete with different percentage of WPSA for M25 and M40 concrete

Sl. No	Concrete Grade	Mix Name	WPSA %	Compressive Strength N/mm^2		
				7 days	28 days	56 days
1	M-25	A1-M25	0	19.75	27.61	28.82
2		B1-M25	5	22.15	28.18	29.12
3		C1-M25	10	24.72	29.97	30.40
4		D1-M25	15	17.27	22.17	22.50
5		E1-M25	20	15.91	19.55	21.29
6	M-40	A2-M40	0	32.77	43.72	44.59
7		B2-M40	5	35.18	45.82	45.73
8		C2-M40	10	38.11	47.32	48.26
9		D2-M40	15	36.21	39.28	40.11
10		E2-M40	20	31.07	36.91	37.47



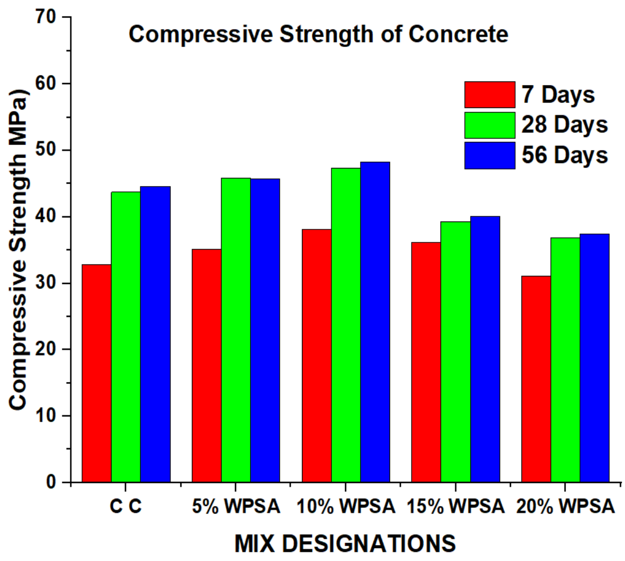


Fig. 4.2: Compressive Strength for the M-25 and M-40 Different Mixes Concrete

The 1.03 % increase in strength for B1-M25 compared to A1-M25 concrete, 5.48 % increase in strength for C1-M25 compared to A1-M25 concrete, 28.0 % decrease in strength for D1-M25 compared to A1-M25 concrete, 35.36% decrease in strength for E1-M25 compared to A1-M25 concrete and 2.55 % increase in strength for B2-M40 compared to A2-M40 concrete, 8.23 % increase in strength for C2-M40 compared to A2-M40 concrete, 11.11 % decrease in strength for D2-M40 compared to A2-M40 concrete, 19.0 % decrease in strength for E2-M40 compared to A2-M40 compared to 56 days' age of concrete.

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C. Split Tensile Strength of concrete with varying waste paper sludge ash

The Split Tensile strength of concrete for different percentages of waste paper sludge ash replacement is presented in Table 4.2, Figure 4.3 it can be observed that there is an increase in Split Tensile strength up to 10% replacement of waste paper sludge ash and beyond that increasing percentage of waste paper sludge ash decrease the Split Tensile strength.

Table 4.2: Split Tensile strength of concrete with different percentage of WPSA for M25 and M40 concrete

Sl. No	Concrete Grade	Mix Name	WPSA %	Split Tensile Strength N/mm^2		
				7 days	28 days	56 days
1	M-25	A1-M25	0	1.82	3.17	3.23
2		B1-M25	5	1.98	3.39	3.45
3		C1-M25	10	2.37	3.62	3.70
4		D1-M25	15	1.65	2.73	2.40
5		E1-M25	20	1.42	2.26	2.31
6	M-40	A2-M40	0	2.19	3.82	3.84
7		B2-M40	5	2.27	3.89	3.90
8		C2-M40	10	2.53	3.97	3.98
9		D2-M40	15	1.70	2.91	2.93
10		E2-M40	20	1.56	2.68	2.73

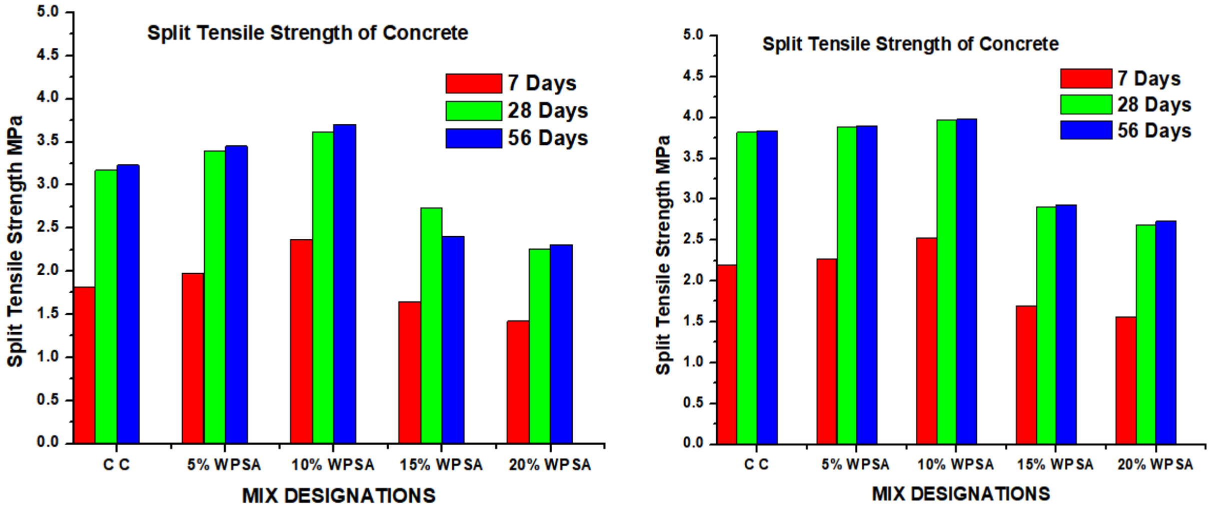

Fig.4.3: Split Tensile Strength for the M-25 and M-40 Different Mixes Concrete

The 6.37 % increase in strength for B1-M25 compared to A1-M25 concrete, 12.77 % increase in strength for C1-M25 compared to A1-M25 concrete, 34.58 % decrease in strength for D1-M25 compared to A1-M25 concrete, 39.82 % decrease in strength for E1-M25 compared to A1-M25 concrete and 1.53 % increase in strength for B2-M40 compared to A2-M40 concrete, 3.64 % increase in strength for C2-M40 compared to A2-M40 concrete, 31.05 % decrease in strength for D2-M40 compared to A2-M40 concrete, 40.65 % decrease in strength for E2-M40 compared to A2-M40 compared at 56 days' age of concrete.

D. Flexural Strength of concrete with varying waste paper sludge ash

The flexural strength of concrete for different percentages of waste paper sludge ash replacement is presented in Table 4.3, Figure 4.4, it can be observed that there is an increase in flexural strength up to 10% replacement of waste paper sludge ash and beyond that increasing percentage of waste paper sludge ash decrease the flexural strength. Beam specimens of size 100 mm *100mm*500 mm so that 10% replacement of waste paper sludge ash is optimum for 7 days, 28 days and 56 days for both M25 and M40 concrete.

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Table 4.3: Flexural strength of concrete with different percentage of WPSA for M25 and M40 concrete

Sl. No	Concrete Grade	Mix Name	WPSA %	Flexural Strength N/mm^2		
				7 days	28 days	56 days
1	M-25	A1-M25	0	3.11	3.67	3.69
2		B1-M25	5	3.29	3.71	3.74
3		C1-M25	10	3.48	3.83	3.85
4		D1-M25	15	2.90	3.29	3.29
5		E1-M25	20	2.79	3.09	3.1
6	M-40	A2-M40	0	4.02	4.62	4.67
7		B2-M40	5	4.15	4.73	4.79
8		C2-M40	10	4.32	4.81	4.85
9		D2-M40	15	4.21	4.38	4.39
10		E2-M40	20	3.90	4.25	4.27

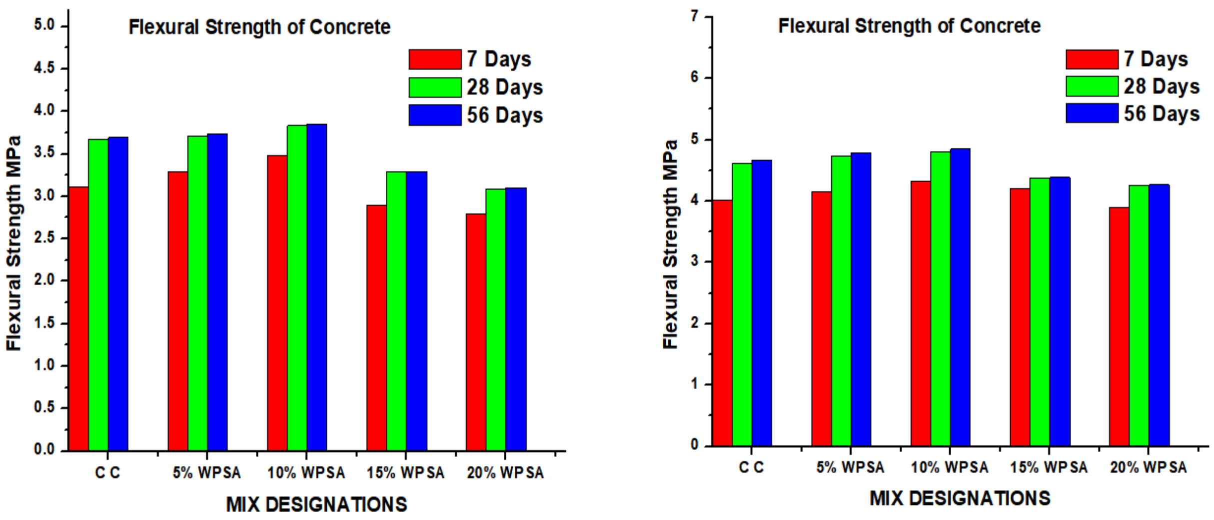

Fig. 4.4: Flexural Strength for the M-25 and M-40 Different Mixes Concrete

The 1.35 % increase in strength for B1-M25 compared to A1-M25 concrete, 2.98 % increase in strength for C1-M25 compared to A1-M25 concrete, 12.15 % decrease in strength for D1-M25 compared to A1-M25 concrete, 19.03 % decrease in strength for E1-M25 compared to A1-M25 concrete and 2.56 % increase in strength for B2-M40 compared to A2-M40 concrete, 3.85 % increase in strength for C2-M40 compared to A2-M40 concrete, 6.37 % decrease in strength for D2-M40 compared to A2-M40 concrete, 9.36 % decrease in strength for E2-M40 compared to A2-M40 compared to 56 days' age of concrete.

E. Water Absorption Test

The average dry weight of concrete cubes specimens after removing from moulds was measured and the average weight of cubes specimens after submerging in water for curing was measured at 28 days of age of curing as shown in Table 4.4. The percentage of water absorption was identified for each concrete specimens and provided an indirect method of durability of concrete. figure 4.5shows the variation of water absorption with different concrete mixes.

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Table 4.4: Water Absorption Test results for 150mm concrete cube specimens for M25 and M40 concrete.

Sl. No	Concrete Grade	Mix Name	WPSA %	Dry Weight of cube (gm)	Wet weight of cube (gm)	Water absorbed (gm)	% of water absorption
1	M-25	A1-M25	0 %	8383	8281	102	1.21%
2		B1-M25	5 %	8350	8455	105	1.25%
3		C1-M25	10 %	8226	8340	114	1.38%
4		D1-M25	15 %	8114	8241	127	1.56%
5		E1-M25	20 %	7996	8134	138	1.72%
6	M-40	A2-M40	0 %	8556	8872	316	3.69%
7		B2-M40	5 %	8538	8872	334	3.91%
8		C2-M40	10 %	8520	8878	358	4.20%
9		D2-M40	15 %	8471	8913	442	5.21%
10		E2-M40	20 %	8449	9011	562	6.65%

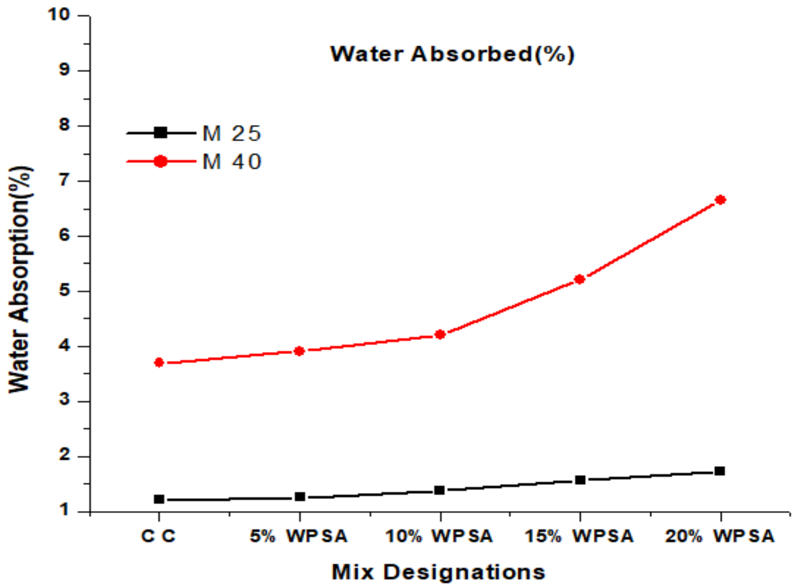

Fig. 4.5: Variation of Water Absorption for 28 days' age of concrete

The water absorption of concrete goes on increasing when waste paper sludge ash is introduced in concrete as partial replacement of cement in concrete, waste paper sludge ash particles absorbed more water as compared to cement and thus increasing the water absorption of concrete. There is nearly 1.21 % water absorption for A1-M25 concrete, 1.25 % water absorption for B1-M25, 1.38 % water absorption for C1-M25 concrete, 1.56 % water absorption for D1-M25 concrete and 1.72 % water absorption for E1-M25 compared to 28 days' age of concrete. Similarly, there is nearly 3.69 % water absorption for A2-M40 concrete, 3.91 % water absorption for B2-M40, 4.20 % water absorption for C2-M40 concrete, 5.21 % water absorption for D2-M40 concrete and 6.65 % water absorption for E2-M40 compared to 28 days' age of concrete

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F. Light Weight Character

The average dry weight of concrete cubes specimens containing 0%, 5%, 10%, 15% and 20% of waste paper sludge ash in place of cement by weight was compared with average dry weight of normal M25 and M40 concrete cubes specimens and the percentage reduces in dry weight was measured is presented in Table 4.5 and figure 4.6. shows the variation of density of concrete with different concrete mixes.

Table 4.5: Dry Weight Density results for concrete cube specimens of size 150mmfor M25 and M40 concrete.

Sl. No	Grade of Concrete	Mix Name	WPSA %	Dry weight of cube with 0% replacement (gm)	Dry weight of cube after replacement (gm)	Dry density of cube (kN/m^3)	Weight reduced (gm)	Change in weight %
1	M-25	A1-M25	0 %	8383	8383	24.36	0	0%
2		B1-M25	5 %	8383	8350	24.27	33	-0.395%
3		C1-M25	10 %	8383	8226	23.91	157	-1.908%
4		D1-M25	15 %	8383	8114	23.58	269	-3.31%
5		E1-M25	20 %	8383	7996	23.24	387	-4.83%
6	M-40	A2-M40	0 %	8556	8556	24.86	0	0%
7		B2-M40	5 %	8556	8538	24.81	18	-0.210%
8		C2-M40	10 %	8556	8520	24.76	36	-0.422%
9		D2-M40	15 %	8556	8471	24.62	85	-1.003%
10		E2-M40	20 %	8556	8449	24.55	109	-1.266%

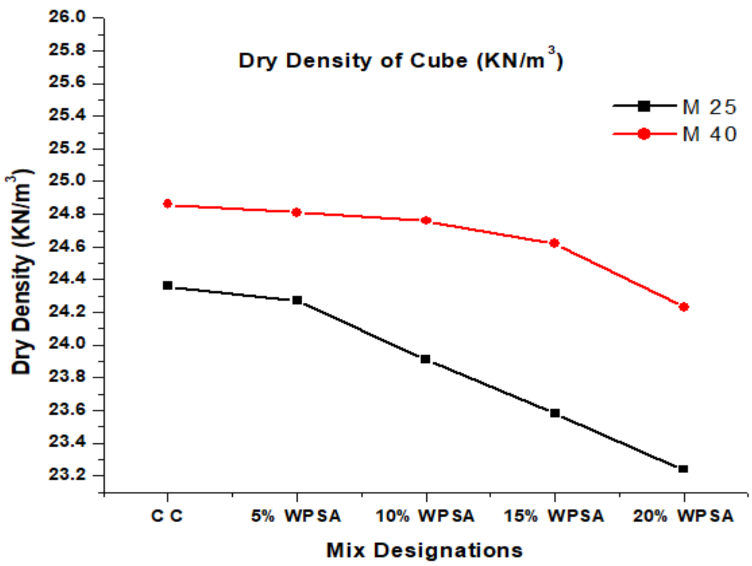

Fig. 4.6: variation of Dry Density of Concrete cubes with different concrete mixes

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The density of concrete goes on decreasing when waste paper sludge ash is introduced in concrete as partial replacement of cement in concrete, compared to reference mix in concrete. The results showed that 4.83 % reduction in dry weight of concrete cubes specimens for mix the E1-M25 as compared to A1-M25 concrete mix and 1.266 % reduction in dry weight of concrete cubes specimens for mix the E2-M40 as compared to A2-M40 concrete 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.

V. CONCLUSION

On the basis results obtained, cement replaced with WPSA, the following conclusions can be drawn out on the M-25 & M-40 concrete:

1. Workability of concrete mix decreases with increase in % waste paper sludge ash concrete in each M-25 & M-40 concrete.
2. Compressive strength increases with an increases in percentage of WPSA up to 10% replacement of cement of 5.48% and 8.23 % beyond 10 % strength decreases gradually at 56 days.
3. Split tensile strength increases with an increases in percentage of WPSA up to 10% replacement of cement of 12.77% and 3.64 % beyond 10 % strength decreases gradually.
4. Flexural strength increases with an increases in percentage of WPSA up to 10% replacement of cement of 2.98 % and 3.85 % beyond 10 % strength decreases gradually at 56 days.
5. With increases in percentage of WPSA content, the water absorption increases on each M-25 & M-40 concrete mix. There is nearly 1.21 % for A1-M25 to 1.72 % water absorption for E1-M25 and 3.69 % A2-M40 to 6.65 % water absorption for E2-M40 compared to 28 days' age of concrete.
6. With increases in WPSA content, results in lighter concrete, the results showed that 4.83 % reduction in dry weight of mix the E1-M25 as compared to A1-M25 concrete mix and 1.266 % reduction in dry weight of concrete mix the E2-M40 as compared to A2-M40 concrete mix.
7. The use of WPSA in concrete will preserve natural sources that are used for cement manufacturing and make concrete construction industry waste paper sludge ash can be used & disposal problem for waste paper sludge ash for paper industries for this waste material is minimized.
8. The use of WPSA in concrete can prove to be an economical as its non-useful waste and free of costs.

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