AN EXPERIMENTAL INVESTIGATION OF USING WASTE PAPER SLUDGE ASH IN CONCRETE MIX

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Abstract: *The primary socio-economic concern of contemporary society is the longevity and sustainability of concrete constructions. In current practice, concrete strength is the primary consideration for this feature. In this study, the mechanical and durability properties concrete containing waste paper sludge ash were evaluated. The compressive strength, split tensile strength, flexural strength, rebound hammer and economic feasibility were conducted to evaluate the mechanical properties of concrete. The factors used in this investigation of waste paper sludge ash (WPSA) were 0, 5, 10, 15, and 20% by cement weight are used. The outcomes of this approach have been shown to be quite similar to the real values.*

Keywords: *Mechanical Properties, Rebound Hammer Analysis, Waste paper sludge ash*

1.0 INTRODUCTION

Concrete stands as a pivotal component in infrastructure, and its design intricacies can render it a robust construction material. Numerous research has shown that various paper industry waste products can be used as building industry raw materials. Paper waste is produced during the first mechanical separation step, and burning it turns it to ash. Stated differently, waste paper sludge ash, or WPSA, is a waste that is generated by the paper industry [1-3]. These products are made when pulp and ink are burned to release energy and decrease their volume. A significant economic and environmental issue facing the paper and board sector is paper mill sludge. Around the world, a huge amount of waste paper sludge is produced. Paper sludge makes up 0.7% of all the urban garbage produced in India [4-6]. Approximately 300 kg of sludge are created for every tone of recycled paper used. In the EU, the combustion process is regulated. Fluidized bed combustion is normally used at temperatures between 850 and 1100 degrees Celsius. The United Kingdom generates 125,000 tons of PSA annually, of which 70% is utilized for low-value uses like spreading land and the remaining 30% is usually disposed of in landfills [7-8]. Greenhouse gases, such as CO_2, are released into the environment during the manufacturing of cement and have the silent killer effect. Four million tons of cement are produced, which releases about a million tons of greenhouse gases into the atmosphere. Applying hypo sludge with pozzolanic addition was recommended for concrete, with decisions left to the engineer's discretion [9].

Other than ettringite, calcium silicate hydrate (C-S-H) is recognized as the primary hydration product of the mortars. It is common knowledge that the C-S-H gel plays a major role in determining the mechanical properties of cement paste by keeping it cohesive. The purpose of NDT is to determine the quality and integrity of materials, components or assemblies without affecting the ability to perform their intended functions. [10-11]. Rebound method plays a vital role in not only the quality control of new concrete construction but also the strength evaluation of existing concrete structures. The use of rebound hammer is suitable to estimate and predict the strength of concrete, which makes engineering judgment quite very easy. The study found the rebound test showed decreasing rebound number which shows a decrease in compressive strength and surface hardness when WPSA is added into the concrete. The Schmidt hammer provides an inexpensive, simple and quick method of obtaining an indication of concrete strength, but accuracy of around up to ±15 per cent is possible. Numerous sites and locations can be tested using NDT because it is quick, simple to use on site, and reasonably priced [12-14].

The aim of this research is

- To determine the mechanical and durability properties of partially replaced WPSA in M25 concrete mixes.
- To determine the quality of concrete mix using Rebound Hammer Analysis.
- To identify the optimum percent of WPSA that can be used in the construction of an economically viable structure.

2.0 MATERIALS

Using a variety of materials, such as cement, fine aggregate, coarse aggregate, water, waste paper sludge ash, and combination, the attributes of each were. Investigated in accordance with the IS regulations. These are the specifics:

2.1 Cement: Ordinary Portland cement of Ultra Tech brand, 53 grades, adhering to IS 12269-2013 standards, was employed. The Table 1 represents the physical characteristics of cement [15].

Table 1: Physical Characteristics of Cement

Sl. No	Characteristics	Value Obtained	As per IS:8112-1989
1	Fineness (%)	5.3	10
2	Specific gravity	3.10	2.5-3.5
3	Standard Consistency (%)	26	30
4	Initial setting time (min.)	40	30
5	Final setting Time (min.)	260	600
6	Compressive strength at 7 days (N/mm^2)	35.53	16.25 (Min)
	14 days(N/mm^2)	49.55	22.5 (Min)
	28 days(N/mm^2)	52.89	31.6 (Min)

2.2 Fine Aggregate: Fractions ranging from 4.75 mm to 150 microns were considered as fine aggregate. Locally available crushed rock sand, conforming to grading zone II under IS 383-1970, was used. The Table 2 represents the properties of fine aggregate [16].

2.3 Coarse Aggregate: Coarse aggregate compressed natural aggregates. Locally sourced crushed stone with sizes of 20 mm down size are 50% and 10mm down size are 50% used, conforming to IS: 383-1970 was used. The Table 3 represents the properties of coarse aggregate [16].

2.4 Water: Drinkable water was used for mixing, casting, and curing. The water-binder ratio was 0.5 for M25 developed mix concrete and water has a pH of 6.5-7 and conforms to all other quality criteria established by Indian standards [17].

2.5 Admixture: Conplast SP430, a high-performance water-reducing admixture, was employed an additive to be used in a concrete mix [18].

Table 2: Properties of Fine Aggregate

Sl. No	Characteristics	Values Obtained	As Per IS:383-1970
1	Specific gravity	2.7	2.5-3.5
2	Free moisture content	3.35	30
3	Water absorption	3.19	30
4	Zone	II	-

Table 3: Properties of Coarse Aggregate

Sl. No	Characteristics	Values Obtained	As Per IS:383-1970
1	Specific gravity	2.65	2.5-3.5
2	Free moisture content (%)	0.45	30
3	Water absorption (%)	0.75	30

2.5 Admixture: Conplast SP430, a high-performance water-reducing admixture, was employed an additive to be used in a concrete mix [18].

2.6 Waste Paper Sludge Ash: Waste paper sludge obtained from South India Paper Mills Pvt. Ltd., Thandavapura, Mysuru, Karnataka, India, the collected samples were sun-dried for 10 to 15 days and incinerated at 700^{o} C to 800^{o} C for 2 hours and convert to it into ash. The ash was further sieved using an Indian standard 90-micron sieve. The specific gravity of the WPSA was found to be 2.45 and fineness of WPSA is 2.8 [9].

3.0 MIX DESIGN AND METHODOLOGY

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 for M25 concrete mix is prepared for this study, the total 5 mix of concrete is prepared 5 of each containing WPSA was in different percentage. The table 4 shows the mix design is done as per IS 10262: 2009 guidelines [19].

Table 4: Concrete Mix Proportions for M25 developed mix Concrete

Concrete Grade	Mix Name	WPSA (%)	WPSA (Kg)	W/C ratio	Cement (Kg/m^3)	FA (Kg/m^3)	CA (Kg/m^3)	Water (Kg/m^3)	Slump (mm)
M25	A1M25	0	-	0.5	334.11	852	1067.6	167	97
	B1M25	5	16.70	0.5	317.4	852	1067.6	167	95
	C1M25	10	33.41	0.5	300.69	852	1067.6	167	92
	D1M25	15	50.11	0.5	283.99	852	1067.6	167	89
	E1M25	20	66.82	0.5	267.28	852	1067.6	167	85

3.1 Workability Test: The workability of various concrete mixes varies. When cement is partially substituted by WPSA, the slump in the concrete decreases. Additionally, the particles of WPSA absorb more water than cement [18].

3.2 Compressive Strength: The compressive strength test is the most crucial of all the concrete tests since it reveals details about the characteristics of the material. Compressive strength is measured using a 150x150x150 mm concrete cube. The compressive strength of conventional concrete and WPSA concrete was assessed at curing ages of 7, 28, 56, and 90 days [20-22]

3.3 Split Tensile Strength: The typical split tensile strength of concrete test is crucial because it regularly yields trustworthy results. The split-tensile strength of concrete is measured using a cylinder with dimensions of 150 mm in diameter and 300 mm in length [21-22].

3.4 Flexural Strength: An experimental specimen of 100 mm by 100 mm by 500 mm is used to determine a concrete component's flexural strength. The flexural strengths of WPSA concrete and ordinary concrete were compared at ages of 7, 28, 56, and 90 days, respectively [22].

3.5 Rebound Hammer Test: Rebound hammer tests are frequently performed to ascertain the correlation between surface hardness and compressive strength of body structures. The specimens for the test using prisms of measuring a 100 mm on a side and 500 mm in length. To cast a 5 mixture proportions of prisms for M25 developed mix concrete are cast for the both the control mix and the Sustainable concrete mix and curing age of 7, 28 and 56 days respectively. The rebound number is the rebound value that is read off on a graded scale. The graph that is located on the hammer's body provides a direct way to determine the compressive strength of concrete.

4.0 RESULTS AND DISCUSSIONS

4.1 Workability Test

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 4. The increase in WPSA noticed that decrease in slump value and Fig 1 shows the variation of slump values with different concrete mixes.

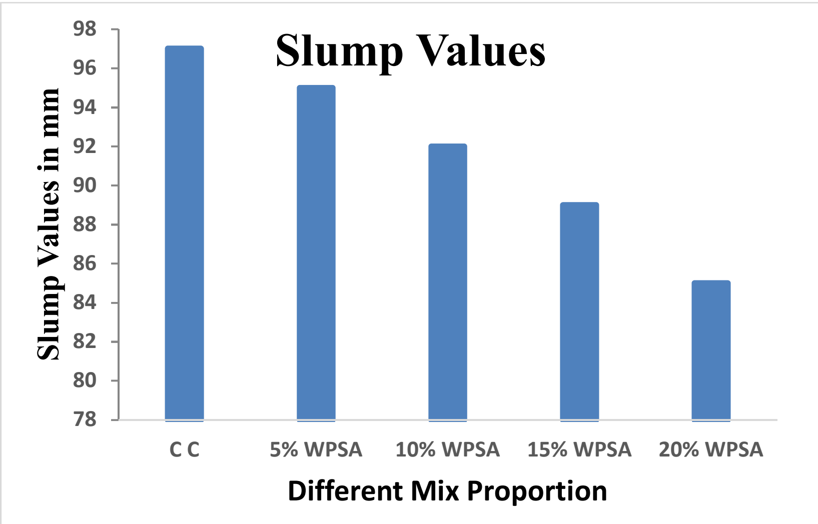

Fig.1 Variation for M25 concrete's slump

A1M25 with 0% paper sludge ash gives 97 mm slump where as in B1M25 with 5% replacement gives 95 mm slump, which goes on decreasing to attain 85 mm slump at 20 % replacement of E1M25 mix respectively.

4.2 Compressive Strength

The Table 5, Figure 2, can be observed that there is an increase in compressive strength up to 10% replacement of WPSA and beyond that increasing percentage of WPSA decrease the compressive strength of concrete.

Table 5: Compressive Strength for M25 Different Mixes Concrete

Sl. No	Mix Type	WPSA (%)	Compressive Strength with Curing Period in days (N/mm^2)			
			7	28	56	90
1	A1M25	0	19.75	27.61	28.82	28.85
2	B1M25	5	22.15	28.18	29.12	29.19
3	C1M25	10	24.72	29.97	30.40	30.43
4	D1M25	15	17.27	22.17	22.50	22.53
5	E1M25	20	15.91	19.55	21.29	21.33

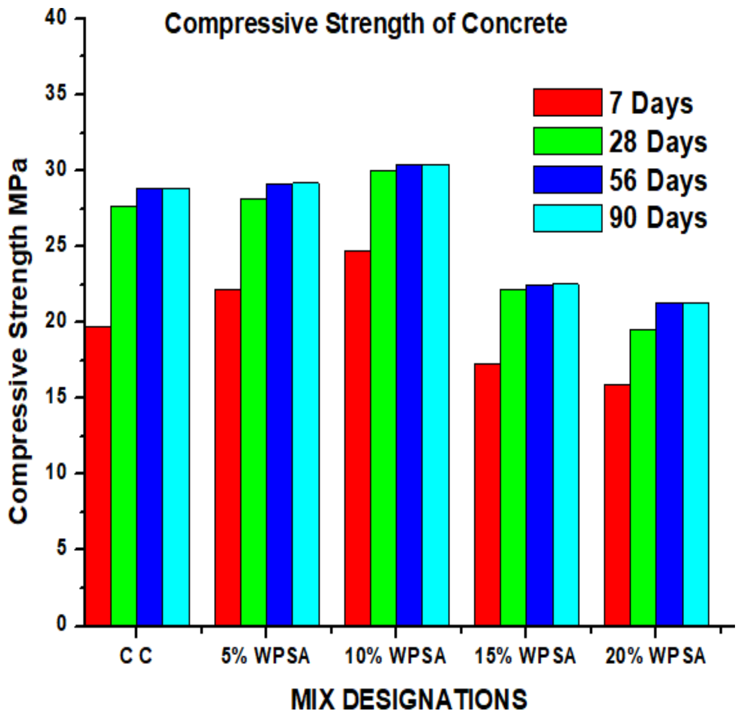

Fig.2 Compressive Strength for M25 Concrete Mixes

Based on the results, it was observed that the concrete mix with 5% WPSA replacement increased the strength slightly, reached a maximum strength at 10% replacement of WPSA in the concrete, and decreased in strength after 15% and 20% replacements of WPSA. In comparison to A1M25 concrete, B1M25 has 1.17 % more strength, C1M25 has 5.47 % more strength, D1M25 has 21.90 % less strength than A1M25 concrete, and E1M25 has 26.06 %

less strength than A1M25 when its 90 days old for M25 grade of concrete.

4.3 Split Tensile Strength

The test results are displayed in Table 6, and Figure 3 illustrates the strength increase for conventional concrete and WPSA concrete at different curing ages (7, 28, 56, and 90 days) based on the split tensile strength at each age of concrete mix.

Table 6: Split Tensile Strength for M25 Different Mixes Concrete

Sl. No	Mix Type	WPSA (%)	Split Tensile Strength with Curing Period in days (N/mm^2)			
			7	28	56	90
1	A1M25	0	1.82	3.17	3.23	3.27
2	B1M25	5	1.98	3.39	3.45	3.52
3	C1M25	10	2.37	3.62	3.70	3.74
4	D1M25	15	1.65	2.73	2.4	2.42
5	E1M25	20	1.42	2.26	2.31	2.36

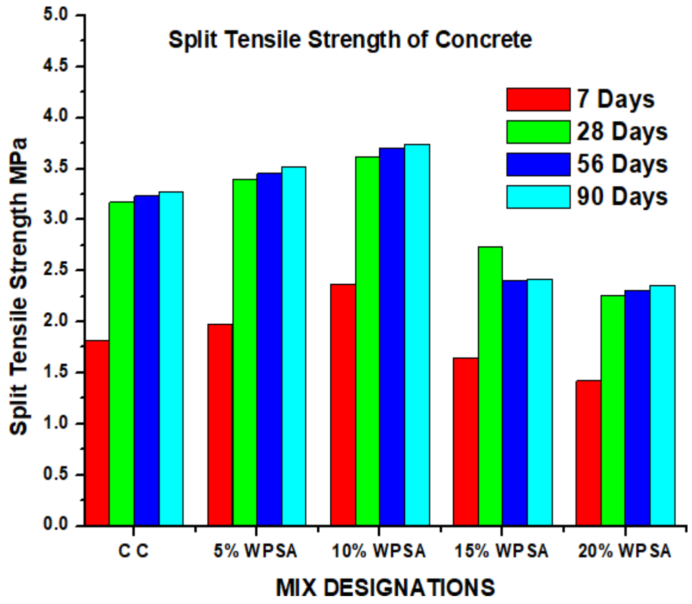

Fig.3 Split Tensile Strength for M25 Concrete Mixes

As a result of the experiments, fig 3 It is clear that the concrete mix with 5% replacement of WPSA has a slightly higher strength than the concrete mix with a replacement of 5% WPSA. At a maximum strength, the concrete has attained a maximum strength at a 10% replacement of WPSA. However, the strength has decreased as the percentage of WPSA in the concrete reaches 15% and 20%. When comparing B1M25 concrete to A1M25 concrete, there is a 7.64 percent increase in strength, a 14.37 percent increase in strength for C1M25 concrete, a 25.9 percent decrease in strength for D1M25 concrete compared to A1M25 concrete, and a 27.8 percent decrease in strength for E1M25 concrete compared to A1M25 concrete.

4.4 Flexural Strength

The test results are displayed in Table 7, and Figure 4 illustrates the strength increase for conventional concrete and WPSA concrete at different curing ages (7, 28, 56, and 90 days) based on the flexural strength at each age of concrete mix.

Table 7: Flexural Strength for M25 Different Mixes Concrete

Sl. No	MixType	WPSA (%)	Flexural Strength with Curing Period in days (N/mm^2)			
			7	28	56	90
1	A1M25	0	3.11	3.67	3.69	3.71
2	B1M25	5	3.29	3.71	3.74	3.78
3	C1M25	10	3.48	3.83	3.85	3.91
4	D1M25	15	2.90	3.29	3.29	3.32
5	E1M25	20	2.79	3.09	3.10	3.17

Based on the results, fig 4 it is observed that the concrete mix containing 5% WPSA has a slight increase in strength, and it reaches its maximum strength at 10% replacement of WPSA to the concrete. The strength decreases after incorporating 15% and 20% WPSA into the concrete mix. In comparison to A1M25 concrete, B1M25 has a 1.88 % strength increase, C1M25 has a 5.39 % strength increase, D1M25 has a 10.51% strength decrease, E1M25 has a 14.55 % strength decrease compared to A1M25 compared to 90 days old of M25 concrete mix.

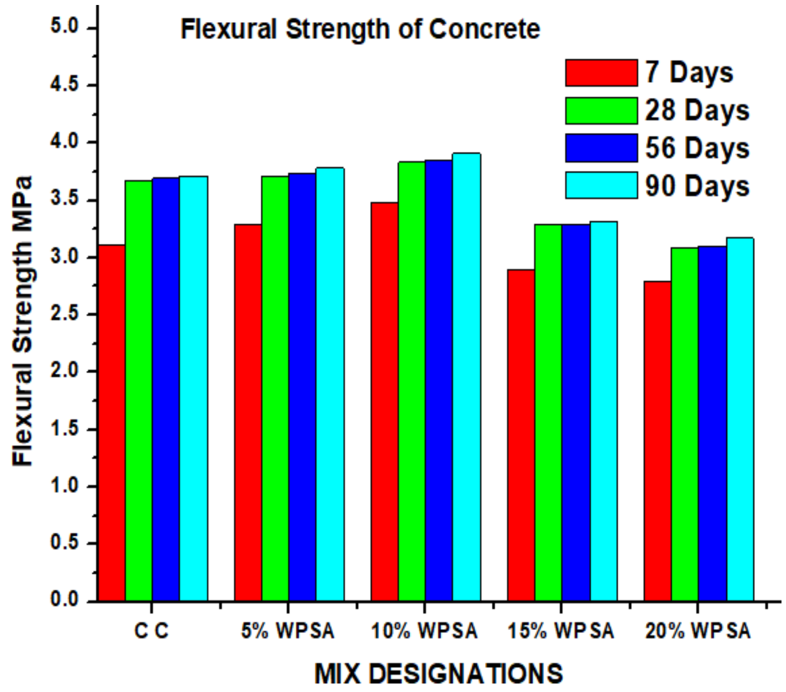

Fig.4 Flexural Strength for M25 Concrete Mixes

4.5 Rebound Hammer Test

The Table 7 shows the rebound number recorded on the prisms specimens is then calculated as the average of rebound number by referring to Schmidt Hammer Graph. Figures 5, display the average compressive strength values for the concrete mix created with M25 developed mix concrete.

Table 7: Rebound Hammer for M25 Concrete Prism

WPSA %	Curing Age	Rebound Value Vertically down			Compressive strength, MPa	Probable Concrete Quality	Average Strength MPa
		Left	Middle	Right			
0%	7 days	22	24	24	10	Fair	11.0
		25	26	24	12	Fair	
		25	26	26	11	Fair	
	28 days	32	36	36	24	Good	22.60
		36	34	34	22	Good	
		34	34	37	22	Good	
	56 days	38	36	38	26	Good	26.66
		38	38	37	26	Good	
		39	38	39	28	Good	
5%	7 days	27	26	26	12	Fair	12.33
		28	25	26	12	Fair	
		28	28	25	13	Fair	
	28 days	35	37	37	25	Good	
		36	37	37	25	Good	25.0

	56 days	38	36	35	25	Good	
		38	41	38	29	Good	
		39	36	38	26	Good	
		38	35	37	26	Good	27.0
10%	7 days	26	28	30	15	Fair	
		28	32	30	16	Fair	15.0
		30	26	28	15	Fair	
	28 days	34	38	36	24	Good	
		38	38	38	28	Good	26.60
		36	39	39	28	Good	
	56 days	40	42	40	31	Very Good	
		39	36	38	26	Very Good	
		38	40	36	28	Very Good	28.30
15%	7 days	26	23	26	12	Fair	
		28	25	25	13	Fair	13.0
		27	28	28	14	Fair	
	28 days	32	37	36	23	Good	
		37	36	36	25	Good	22.30
		32	33	36	19	Good	
	56 days	34	37	34	23	Good	
		34	32	35	20	Good	
		33	35	32	20	Good	21.0
20%	7 days	25	23	23	10	Fair	
		27	24	24	12	Fair	11.0
		26	26	24	12	Fair	
	28 days	34	32	32	20	Good	
		33	30	31	18	Good	18.0
		32	32	31	18	Good	
	56 days	26	30	31	15	Fair	
		32	33	28	17	Fair	
		27	30	30	15	Fair	15.0

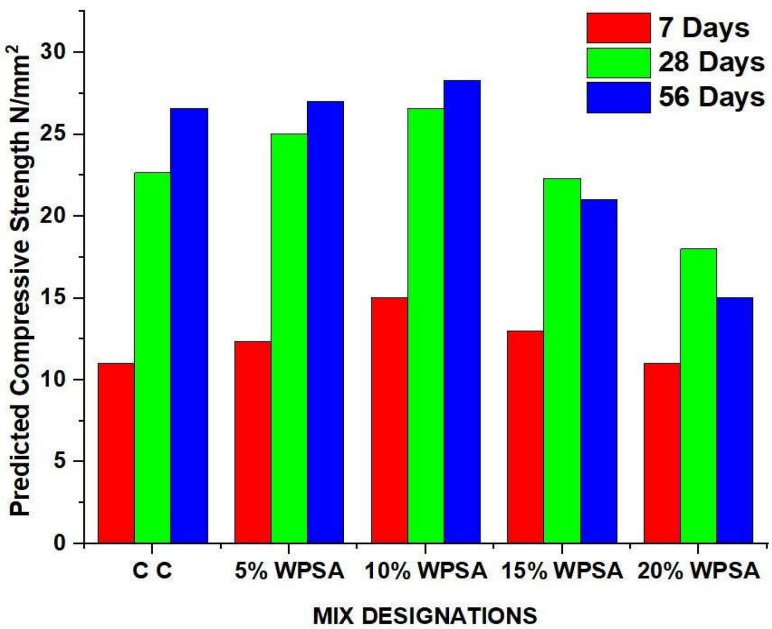

Fig.5 Rebound Hammer for M25 Concrete Prism

The figure 5 shows the average compressive strength of 37 MPa in the absence of WPSA addition. The average compressive strength, represented by the addition of 5% WPSA, is 36 MPa, and the addition of 10% WPSA, 38 MPa. After 56 days of concrete age for M25 grade concrete, the average compression strength then begins to steadily decline upon adding 15% and 20% of WPSA, or 32.66 MPa and 26.6 MPa respectively.

4.6 Financial Viability

The cost of conventional concrete is determined by the cost of cement and other building materials, such as aggregates, water, and other additives. Cost analysis is done to determine the ideal percentage of WPSA for M25 concrete mix, and the results are compared to the cost of conventional concrete. Other factors that may affect material costs include transportation, availability of the material, and market demand.

a**. Expense for materials**

Cement price per bag = 410 Rs,

The price per cum of crushed rock sand = 1600 m^3

Cost of coarse aggregate per cum = 1150 m^3

Cost of WPSA per kg = 1 Rupee

Table 8: Cost of materials for M25 developed mix concrete per cum

Percentage replacement of cement	Materials	Quantity of materials kg/m^3	Cost Rs.	Cost of materials Rs.	Total cost Rs.	% change in cost
	C	334.11	8.2 /kg	2739.70		
0 %	FA	852.0	1600 /m^3	804.0		
	CA	1067.6	1150 /m^3	533.89	4077.59	-
	WPSA	-	1 /kg	-		
	C	317.41	8.2 /kg	2602.76		
5 %	FA	852.0	1600 /m^3	804.0	3957.35	-2.94
	CA	1067.6	1150 /m^3	533.89		
	WPSA	16.70	1 /kg	16.70		
	C	300.70	8.2 /kg	2465.74		
10%	FA	852.0	1600 /m^3	804.0	3837.04	-5.89
	CA	1067.6	1150 /m^3	533.89		
	WPSA	33.41	1 /kg	33.41		
	C	284.0	8.2 /kg	2328.8		
15 %	FA	852.0	1600 /m^3	804.0	3716.8	-8.84
	CA	1067.6	1150 /m^3	533.89		
	WPSA	50.11	1 /kg	50.11		

	C	267.30	8.2 /kg	2191.86		
20 %	FA	852.0	1600 /m^3	804.0	3596.57	-11.80
	CA	1067.6	1150 /m^3	533.89		
	WPSA	66.82	1 /kg	66.82		

*Cement *Fine aggregate *Coarse aggregate *WPSA= Waste Paper Sludge Ash

The compared values of cost show gradual decrement in total cost of per cubic meter of concrete compared to conventional concrete. The above table shows the cost values up to 5 to 20% replacement of WPSA in cement replacement and the difference in cost from conventional concrete to partially replaced concrete was 481.02 Rs. for M25 developed mix concrete respectively.

5.0 CONCLUSIONS

1. The Workability of concrete mix decreases with increase in percentage of WPSA content for M25 developed concrete Mix.
2. The Compressive strength increases with increases in percentage of WPSA up to 10% replacement of cement is 5.47% beyond 10 % strength decreases gradually at 90 days age of concrete.
3. The Split tensile strength increases with increases in percentage of WPSA up to 10% replacement of cement is 14.34 % beyond 10 % strength decreases gradually at 90 days age of concrete.
4. Flexural strength increases with increases in percentage of WPSA up to 10% replacement of cement is 5.39 % beyond 10 % strength decreases gradually at 90 days age of concrete.
5. For the purpose of estimating the strength of concrete, the rebound number approach yields findings that are dependable, almost exact, and attain an acceptable degree of precision.
6. The concrete mixes can be reduced in cost by using 5%, 10%, 15%, and 20% of WPSA instead of ordinary Mix. Therefore, up to 20% of WPSA can be applied as cost-effective and environmentally beneficial filler to structural elements.

Future research will focus on the following topics in light of the study's findings and recommendations:

a. Durability behavior of WPSA materials to investigate the consequence of severe climate conditions on mechanical strength.

b. Environmental behavior during the curing time by analyzing the possible presence metals. Leaching tests are recommended on waste paper sludge ash materials and mixtures. Both behavior studies could be coupled.

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