Partial Replacement Of Cement With Waste Paper Sludge In Addition With Activated Charcoal Powder

Sumit Gaikwad, Sudhanshu Pathak, Mahesh Tatikonda

Abstract— The global cement industry contributes about 5% of greenhouse gas emission to the earth's atmosphere. In order to reduce bad environmental effects associated with cement, there is a need to develop alternatives which make the concrete industry sustainable. The industrial waste paper sludge (PS) is used for study which is generally dumped to the nearest site which polluted the land and atmosphere as well as it also affects the aesthetics of urban environment. The study examines the possibility of using waste paper sludge (PS) as partial replacement of cement in a quantity of 5%, 10%, 15% and 20%. Coconut shell based activated charcoal powder (ACP) is used as an additive in concrete with 1%, 2% and 3% by weight of cement. The target strength of the concrete mix is 40 N/mm2. Mechanical properties of combination and their individual performance were studied and compared with conventional concrete. Compressive strength, Split-tensile strength, and flexural strength tests were conducted at the age of 3, 7 and 28th days and it has been observed that optimum value of PS is 10% and ACP is 1%. A durability test was conducted by Rapid Chloride Penetration Test (RCPT) confirming to ASTM C1202. PS 10% replacement results observed raise in 13.15% as compared to conventional concrete and addition of ACP observed raise in 10.58% as compared to conventional concrete. In Durability study, it has been observed that a combination of PS10% + ACP 1% is more durable compared to conventional concrete.

Index Terms— ACP, Cement replacement, Compressive strength, Flexural strength, PS, RCPT, Split tensile strength.

1 INTRODUCTION

CEMENT as a commodity plays a vital role in the growth of a nation since it is an essential raw material for concrete which is a key raw material in key sectors like infrastructure, construction, commercial and residential real estate. Globally, cement contributes about 5% of the total CO2 emissions. After water concrete is the second most substance consumed on Earth. In India, the cement sector is one of the prominent contributors to conventional as well as GHG emissions. Over 3.3 billion tons of cement was consumed globally in 2010 based on a survey of world coal association and also cement production emits CO2 into the atmosphere which is harmful to nature. If we can partially replace the cement with the material with desirable properties then we can save natural material and reduce the emission of CO2 into the atmosphere. As per the research papers, there is an Identification of alternative material from Paper mill i.e. Paper Sludge as a cement replacement material, this waste material is hazardous to the environment. During the paper manufacturing process, a huge amount of solid waste is produced and this waste is consuming a large percentage of local landfill space. As it increases pollution problem it is necessary to dispose of or reuse this solid waste. This project reports on the results of an investigation of utilization of paper waste, as material in concrete. This waste is dumping to the nearest site which spoils the land and atmosphere as well as it also affects aesthetics of urban environment so the use of this waste material in Cement is cost effective as well as an environment-friendly way to dispose of waste. The use of paper sludge as a cement replacement is one option that can reduce sludge disposal problem. In this case, studies are needed to study the performance of concrete using paper sludge as a cement replacement material. In this study examines the possibility of using waste paper sludge (PS) as partial replacement of cement with Target strength of 50 N/mm2. Examination of compressive strength, tensile strength, and flexural strength are done for 28 days and this mix is compared with conventional concrete.

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2 MATERIAL

2.1 Cement

Ordinary Portland Cement of Birla super brand of Grade-53 was used in this study. Special care was taken to ensure that the cement is from the latest batch of packing. Specific gravity of cement was obtained as 3.13.

TABLE 1 PROPERTIES OF CEMENT

Sr. No.	Properies of Cement	Results
1	Specific Gravity	3.15
2	Standard Consistency (%)	32
3	Initial Setting Time	35 min
4	Final Setting Time	3 hr 45 min

2.2 Sand

Those fractions from 4.75 mm to 150 microns are termed as fine aggregate. In this investigation locally available River sand is used as fine aggregate.

TABLE 2 PROPERTIES OF SAND

Sr. No.	Properies of Fine Aggrigate	Results
1	Specific Gravity	2.38
2	Fineness Modulus	3.35
3	Silt Content (%)	3.75
4	Water absorption (%)	1.20
5	Bulk Density (gm/cc)	1753

2.3 Coarse Aggregate

Coarse aggregate includes natural aggregates. Locally available crushed stone of 10mm and 20 mm sizes have been used as coarse aggregate. The physical properties of coarse aggregate were tested.

TABLE 3 PROPERTIES OF AGGRIGATE

Sr. No.	Properies of Aggrigate	Results	
		10mm	20mm
1	Specific Gravity	2.69	2.76
2	Fineness Modulus	3.19	7.54
3	Water absorption (%)	1.35	1.83
4	Bulk Density (gm/cc)	1711	1741

2.4 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.

2.5 Admixture

Conplast SP500 is used for High performance water reducing and super plasticizing admixture.

2.6 Waste Paper Sludge

Waste material Obtained from Paper Industries named as Ballarpur Industries Limited (BILT), Chandrapur. The nature of PS is shown in following Image.

Fig: 1

Fig: 2

TABLE 3 CHEMICAL PROPERTIES OF PS

Sr No	Constituent	Results %
1	Moisture	56.8
2	Magnesium Oxide (Mgo)	3.3
3	Calcium Oxide (CaO)	46.2
4	Loss of Lignescent	27
5	Acid insoluble	11.1
6	Silica (SiO2)	9
7	R2O3	3.6

2.7 Activated Charcoal Powder water

Coconut shell based Activated charcoal powder is used as an additive in cement having sieved with 90µm size.

Fig: 3

2.8 PS + ACP

The combination of optimum value i.e. PS (10%) and optimum value i.e. ACP (1%) is used in cement for better results. Following fig shows combination of PS and ACP.

Fig. 4

3 Methodology

3.1 Sample Collection

Paper sludge Sample is collected from Paper manufacturing industry and Activated charcoal powder from the supplier.

3.2 Mix Proportion

All the specimens were prepared by mechanical mixing in accordance with IS: 2250-1981. The Conventional concrete of M40 grade with constant Water/cement ratio (W/C) of 0.40 was prepared without replacement of cement. Cement was partially replaced by Waste Paper Sludge (WPS) with 5%, 10%, 15% and 20% and adding ACP with 1%, 2% and 3%.

TABLE 4 MIX PROPORTION FOR PS

Sr. No.	Material for $1M^3$	% Replacement				
		0%	5%	10%	15%	20%
1	Cement	470.00	446.50	423.00	399.50	376.00
2	CA 10mm	461.00	461.00	461.00	461.00	461.00
3	CA 20mm	691.00	691.00	691.00	691.00	691.00
4	R. Sand	648.00	648.00	648.00	648.00	648.00
5	Water	160.00	160.00	160.00	160.00	160.00
6	Admixture	4.70	4.70	4.70	4.70	4.70
7	WPS	0.00	23.50	47.00	70.50	94.00

TABLE 5 MIX PROPORTION FOR ACP

Sr. No.	Material for $1M^3$	% Addition		
		1%	2%	3%
1	Cement	470.00	470.00	470.00
2	CA 10mm	461.00	461.00	461.00
3	CA 20mm	691.00	691.00	691.00
4	R. Sand	648.00	648.00	648.00
5	Water	160.00	160.00	160.00
6	Admixture	4.70	4.70	4.70
7	ACP	4.70	9.40	14.10

3.3Casting

Total 9 Cubes per sample of Size 150 X 150 X 150 mm is casted for Compressive strength test, 3 Beams per sample of Size 700 X 150 X 150 mm casted for Flexural strength test and 3 Cylinders per sample of Size 300 X 150 mm were casted for Split tensile strength and cured all these samples for 28 days.

Fig: 5

Fig: 6

3.4 Curing

Casted samples were put in curing tank for curing period of 28 days.

Fig: 7

3.5 Testing

3.5.1 Compressive strength test

As we all know that concrete is a mixture of sand, cement, and aggregate. The strength of the concrete depends upon many factors like individual compressive strength of its constituents (Cement, Sand, aggregate), quality of materials used, air entrainment mix proportions, water-cement ratio, curing methods and temperature effects. Compressive strength gives an idea of the overall strength. Through conducting this test, one can easily judge the concrete strength psi and quality of concrete produced. It is calculated using formula P/surface area. This test is performed and taking readings of 3day 7 day and 28th days.

Fig: 8

3.5.2 Flexural Strength test

As per IS516:1959 Methods of tests for Flexural strength test is taken, the flexural strength represents the highest stress experienced within the material at its moment of yield. It is measured in terms of stress. It is determined using formula given as below: 1. If a > 200 then fb = PL/bd2 2. If a < 0.2 or a > 0.17 then fb = 3Pa/bd2. This test is performed and taking readings of 28th days.

Fig: 9

3.5.3 Split tensile strength test

Concrete is very low in tension. The tensile strength of concrete is an important property which affects the extent & width of cracks in the structure. A good concrete should have a tensile strength of 1/10 times that of compressive strength. As per IS 456: 2000 the tensile strength of concrete can be calculated from characteristic cube compressive strength. Tensile Strength of Concrete is calculated by using formula $2P/\pi dl$ for cross check using formula $0.7\sqrt{fck}$ N/mm2. This test is performed and taking readings of 28th days.

Fig: 10

3.5.4 Rapid chloride permeability test (RCPT)

This test was taken on 28th day cured sample and compared with conventional.

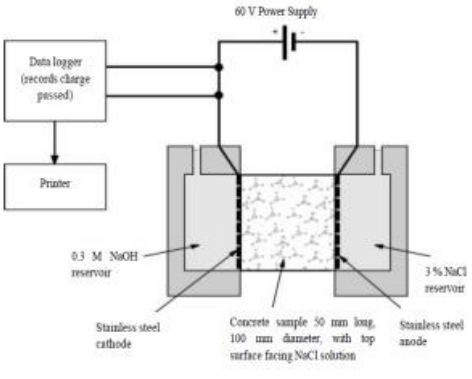


Figure 3. AASHTO T277 (ASTM C1202) test setup.

Fig: 11

Fig: 12

Fig: 13

4 CALCULATIONS

All calculations made using excel sheet, following table shows quantity calculations for cube, beam and cylinder.

TABLE 7 QUANTITY CALCULATIONS

Quantity Calculations

	Volume	1 M³	Cube		Beam		Cylinder	
			0.003375		0.01575		0.005301281	
Sr. No.	Material used for M50	Quantity for 1 cum	Quantity for 1	9	Quantity for 1	3	Quantity for 1	3
1	Cement	470	1.586	14.276	7.403	22.208	2.492	7.475
3	CA (10mm)	461	1.556	14.003	7.261	21.782	2.444	7.332
4	CA (20mm)	691	2.332	20.989	10.883	32.650	3.663	10.990
5	R Sand	648	2.187	19.683	10.206	30.618	3.435	10.306
6	Water	160.000	0.540	4.860	2.520	7.560	0.848	2.545
7	Admixture	4.700	0.016	0.143	0.074	0.222	0.025	0.075

Cube		
Replacement %	Cement	Material
0	14.276	0.000
5	13.562	0.714
10	12.849	1.428
15	12.135	2.141
20	11.421	2.855
Total	64.243	7.138

Beam		
Replacement %	Cement	Material
0	22.208	0.000
5	21.097	1.110
10	19.987	2.221
15	18.876	3.331
20	17.766	4.442
Total	99.934	11.104

Cylinder		
Replacement %	Cement	Material
0	7.475	0.000
5	7.101	0.374
10	6.727	0.747
15	6.354	1.121
20	5.980	1.495
Total	33.637	3.737

Cube		
Addition %	Cement	Material
0	14.276	0.000
1	14.276	0.143
2	14.276	0.286
3	14.276	0.428
Total	57.105	0.857

Beam		
Addition %	Cement	Material
0	22.208	0.000
1	22.208	0.222
2	22.208	0.444
3	22.208	0.666
Total	88.830	1.332

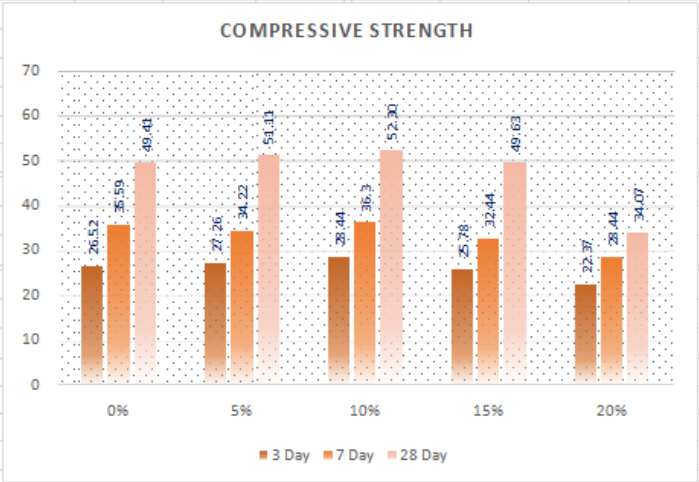
Cylinder		
Addition %	Cement	Material
0	7.475	0.000
1	7.475	0.075
2	7.475	0.149
3	7.475	0.224
Total	29.899	0.448

5 RESULTS

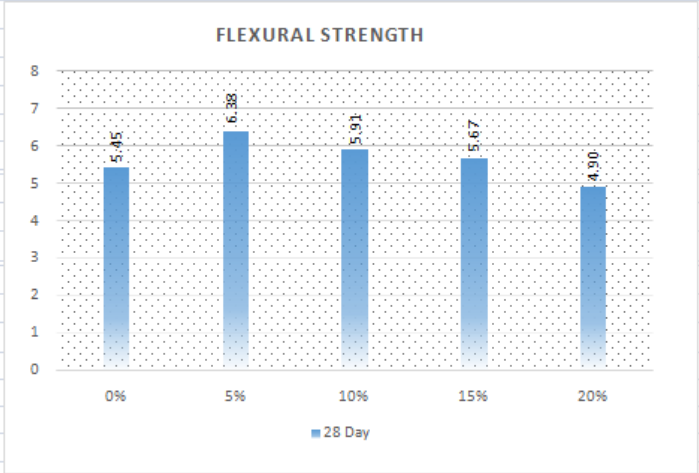
5.1 Replacement of cement with PS

TABLE 8 REPLACEMENT OF CEMENT WITH PS

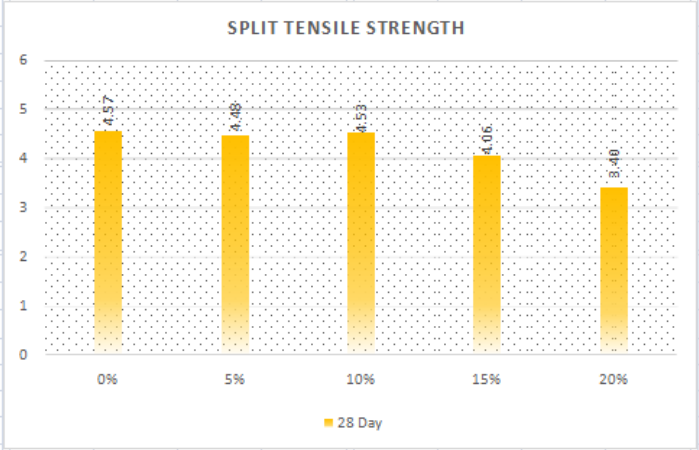
Replacement with Paper Sludge (PS)					
COMPRESSIVE STRENGTH					
	0%	5%	10%	15%	20%
3 Day	26.52	27.26	28.44	25.78	22.37
7 Day	35.59	34.22	36.3	32.44	28.44
28 Day	49.41	51.11	52.30	49.63	34.07
FLEXURAL TENSILE STRENGTH					
	0%	5%	10%	15%	20%
28 Day	5.45	6.38	5.91	5.67	4.90
SPLIT TENSILE STRENGTH					
	0%	5%	10%	15%	20%
28 Day	4.57	4.48	4.53	4.06	3.40



Graph 1: COMPRESSIVE STRENGTH OF PS



Graph 2: FLEXURAL STRENGTH OF PS

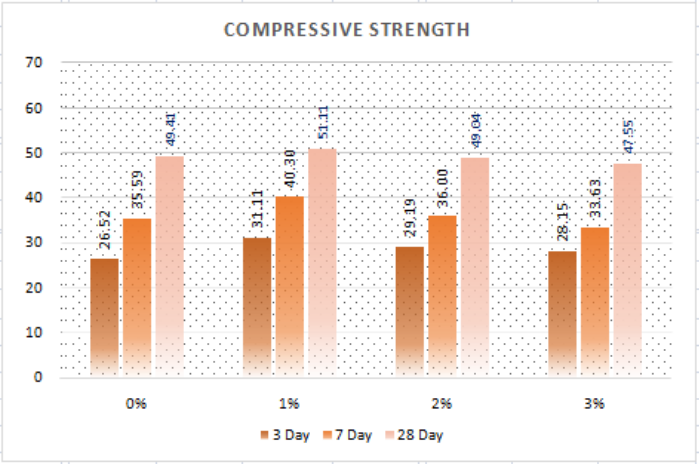


Graph 3: SPLIT-TENSILE STRENGTH OF PS

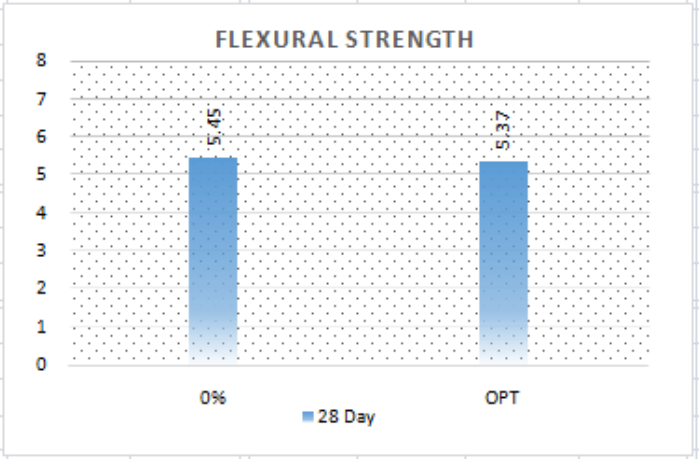
5.2 Addition of ACP in Cement

TABLE 9 ADDITION OF ACP IN CEMENT

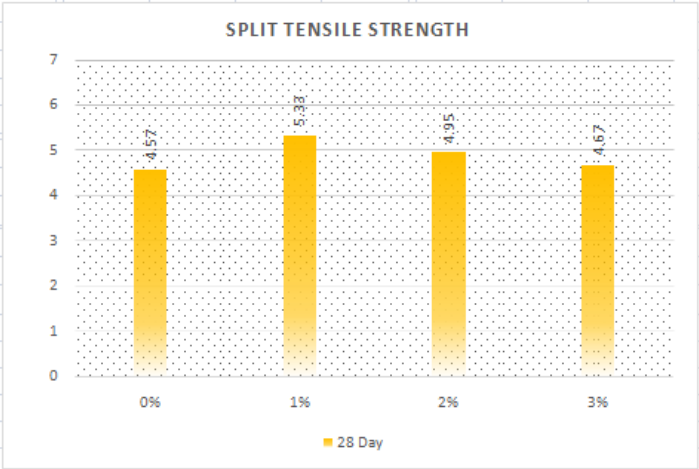
Addition with Activated Charcoal Powder (ACP)				
COMPRESSIVE STRENGTH				
	0%	1%	2%	3%
3 Day	26.52	31.11	29.19	28.15
7 Day	35.59	40.30	36.00	33.63
28 Day	49.41	51.11	49.04	47.55
FLEXURAL TENSILE STRENGTH				
	0%	1%	2%	3%
28 Day	5.45	5.37	5.66	6.08
SPLIT TENSILE STRENGTH				
	0%	1%	2%	3%
28 Day	4.57	5.33	4.95	4.67



Graph 4: COMPRESSIVE STRENGTH OF ACP



Graph 5: FLEXURAL STRENGTH OF ACP

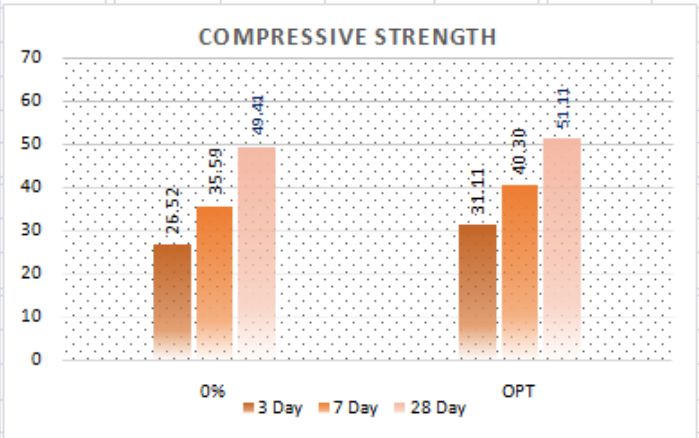


Graph 6: SPLIT-TENSILE STRENGTH OF ACP

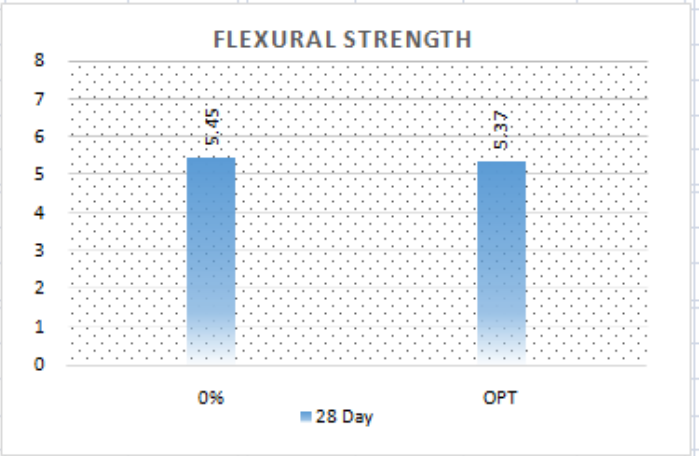
5.3 Replacement of Cement with the combination of 10% PS and 1% ACP

TABLE 9 ADDITION OF ACP IN CEMENT

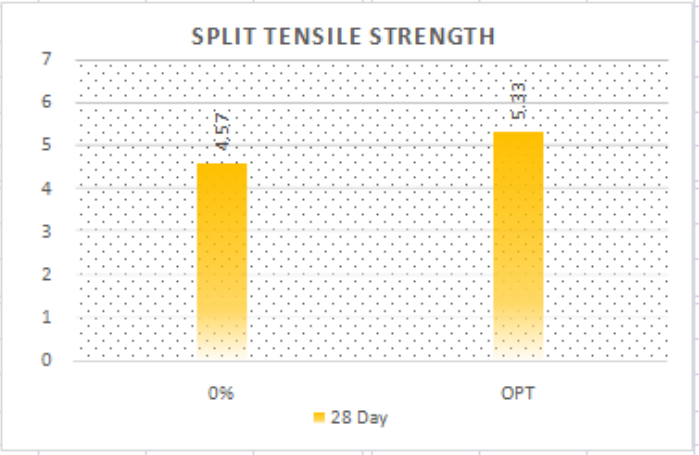
COMPRESSIVE STRENGTH		
	0%	OPT
3 Day	26.52	31.11
7 Day	35.59	40.30
28 Day	49.41	51.11
FLEXURAL TENSILE STRENGTH		
	0%	OPT
28 Day	5.45	5.37
SPLIT TENSILE STRENGTH		
	0%	OPT
28 Day	4.57	5.33



Graph 7: COMPRESSIVE STRENGTH OF PS + ACP



Graph 8: FLEXURAL STRENGTH OF PS + ACP



Graph 9: SPLIT-TENSILE STRENGTH OF PS + ACP

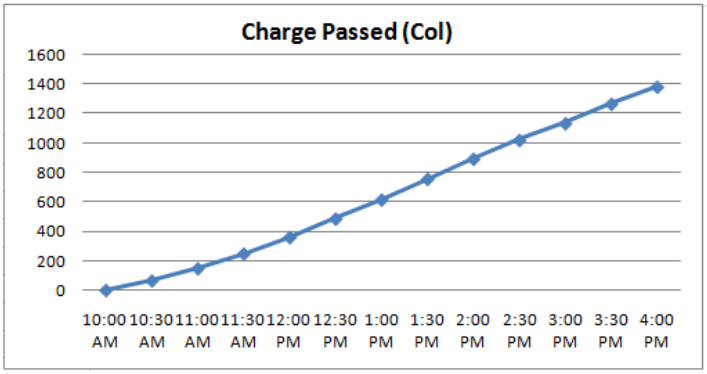
5.2 Rapid chloride permeability test (RCPT)

TABLE 10 RCPT RATINGS

RCPT Ratings (per ASTM C1202)	
Charge Passed (coulombs)	Chloride Ion Penetrability
> 4000	High
2000 - 4000	Moderate
1000 - 2000	Low
100 - 1000	Very Low
< 100	Negligible

TABLE 11 RCPT TEST RESULTS FOR CONVENTIONAL 0%

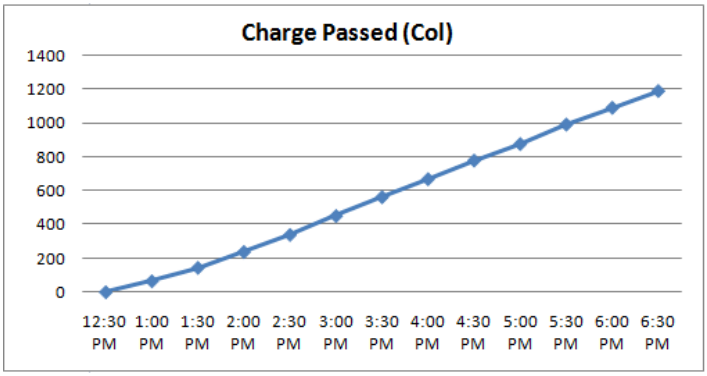
RCPT Test Results for (Conventional 0%)					
Sr. No.	Time (hr:mm)	Time Required (Sec)	Current (mA)	Current (Amp)	Charge Passed (Col)
1	10:00 AM	0	30	0.03	0
2	10:30 AM	1800	36	0.036	64.8
3	11:00 AM	3600	41	0.041	147.6
4	11:30 AM	5400	46	0.046	248.4
5	12:00 PM	7200	50	0.05	360
6	12:30 PM	9000	54	0.054	486
7	1:00 PM	10800	57	0.057	615.6
8	1:30 PM	12600	60	0.06	756
9	2:00 PM	14400	62	0.062	892.8
10	2:30 PM	16200	63	0.063	1020.6
11	3:00 PM	18000	63	0.063	1134
12	3:30 PM	19800	64	0.064	1267.2
13	4:00 PM	21600	64	0.064	1382.4



Graph 10: RCPT FOR CONVENTIONAL CONCRETE

TABLE 12 RCPT TEST RESULTS FOR PS 10% + ACP 1%

RCPT Test Results for (PS 10% + ACP 1%)					
Sr. No.	Time (hr:mm)	Time Required (Sec)	Current (mA)	Current (Amp)	Charge Passed (Col)
1	12:30 PM	0	30	0.03	0
2	1:00 PM	1800	36	0.036	64.8
3	1:30 PM	3600	40	0.04	144
4	2:00 PM	5400	44	0.044	237.6
5	2:30 PM	7200	47	0.047	338.4
6	3:00 PM	9000	50	0.05	450
7	3:30 PM	10800	52	0.052	561.6
8	4:00 PM	12600	53	0.053	667.8
9	4:30 PM	14400	54	0.054	777.6
10	5:00 PM	16200	54	0.054	874.8
11	5:30 PM	18000	55	0.055	990
12	6:00 PM	19800	55	0.055	1089
13	6:30 PM	21600	55	0.055	1188



Graph 11: RCPT FOR PS 10% + ACP 1%

5 CONCLUSION

1. From this study, it is concluded that the combination of waste paper sludge and Activated charcoal powder is a good substitute for cement in the production of concrete.
2. There was an increase in compressive strength of about 10% PS and 1% ACP at 28 days for replacement of cement compared to the reference mix of M40 concrete.
3. The combination of Waste Paper sludge and activated charcoal powder in concrete was good in terms of flexural strength and gave higher results for 5% PS replacement and 3% ACP addition than the reference mix.
4. The combination of 10% PS and 1% ACP gives better results for the split tensile strength.
5. After performing RCPT on optimum material i.e. 10% PS and 1% ACP the results shows durability is raise than conventional.
6. From the cost comparison of paper sludge concrete with conventional concrete, it was found that the it is economical for bulk works.

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