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An Experimental Investigation of Sustainable Concrete by using Paper Pulp and Crusher Dust

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Abstract- The objective of the research carried out in this paper highlights the critical sustainability parameter of reusability of waste materials in the construction sector of India. This paper followed firstly the intense literature survey to identify the waste materials for the replacement in the concrete mix, hereafter Paper Pulp (P.P) and Crusher Dust (C.D) indicates the similar nature like cement and sand respectively. Secondly, an assumed proportion of replacement of P.P by 2.5%, 5%,7.5%,10%, and 12.5% by cement, and 10%, 20%, and 30% replacement of C.D by sand is adopted in M20 mix design by volume method. Thirdly, the casting of 48 sample cubes size of 150 mm × 150 mm × 150 mm is performed for Average Compressive Strength test, and casting of 48 cylindrical cubes of 150 mm in diameter and 300 mm long for Split Tensile Strength. Fourthly, the results are carried out for 7th day testing along with 28th day testing for both tests along with slump variation of different samples. It is observed after the experimental analysis that the elite results compared to normal M_{20} mix are exhibited when the replacement variation of P.P is 5% along with 10% variation of C.D for both Average Compressive Strength and Split Tensile test. In addition to it, the highest slump is obtained for replacement variation of 12.5% P.P and 10%C.D.

Key Words - Concrete, Crusher Dust (C.D), Paper Pulp (P.P), Reusability.

I. INTRODUCTION

Countries which are in evolving phase such as India, where various industrial development projects and rapid urbanization are increasing swiftly to improve the quality of life, the major problem noticed is pollution due to waste [1] [2]. This takes place because of the expansion of domestic and industrial pollution. Since solid waste disposal has become a major problem in metropolitan areas of India [3]. Out of several wastes from different industries, the paper pulp industry produces considerable amounts of wastewater from various types of pulp and in addition, the manufacturing of paper generates heavy dust during the conversion process. Currently, the disposal solution in India is majorly landfilling the earth, although paper sludge is a non-corrosive material [4]. Due to limited landfill space availability and strict regulations, manyresearchers are trying to develop reasonable, economical, and environmentally friendly [5]. Therefore, civil engineers have been challenged to see this potential to use this waste as a constituent in different building materials like sand, bricks, cement, etc. The use of this waste in construction will firstly provide a solution for waste problems and secondly, it will develop a new sustainable resource to materials in different construction projects [6].

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The use of paper pulp and crusher dust established reasonable replacement of cement and fine aggregate in concrete mixes. [7] [8]. A study is needed to determine the contribution of paper sludge and crusher dust in the concrete industry. Although there is great concern about the strength and durability of concrete produced by replacement materials. This requires experimental investigation along with a literature study to verify that the concrete is durable and possess similar or better physical properties like ordinary concrete [9].

II. MATERIALSUSED

The materials used in this experimental research are cement, sand (F.A), paper pulp, crusher dust, coarse aggregate (C.A), and water**.** Firstly, Ordinary Portland cement of brand "Ultratech", Grade 43 confirmed from IS:8112-2013 is adopted. [10] Secondly, the sand of zone II confirmed from IS:383-1970 is used and acquired from local dealer [11]. Thirdly, paper pulp, and crusher dust are also collected from a local distributor. Fourthly, the coarse aggregate of size 20mm is preferred and conforming from IS 383, and the test data materials after experiments are shown below in Table 1.

Table 1 Experimental test data of materials

Specific Gravity	Water absorption	Free (surface) moisture
C.A : 2.84	C.A : 0.55%	C.A : Nil
F.A : 2.64	F.A : 2.71%	F.A : Nil

A. Paper pulp

The acceptance of paper pulp in concrete industries has become an legal use of ordinary concrete pozzolan [12] [13]. The main reason for making use of paper waste is because it provides environmentally friendly facilities [14] [15]. The chemical analysis supported by the XRF (Energy Dispersive X-ray Fluorescence Spectrometer) scan data shows the absorption sheet contains the SI (60%) and Ca (14%) shown in Table 1, and the results of the analysis and storage are represented in Table 2 and Table 3 [16] [17]. Various investigations have confirmed that its Fibrous environment offers high storage quality, while paper-dried waste absorbs water for 24 hours and remains machine-free to achieve consistency [18] [19].

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Table 2 Elemental Analysis of Paper Pulp [16][20]

Elements	Paper Pulp (%)
O	15.83
Ca	14.94
Si	60.57
Al	2.06
Mg	3.59
S	1.07
Ti	0.15
K	0.16
Fe	0.92
Na	0.22
Cu	0.05
P	0.03
Cl	0.41

Table 3 Proximate Analysis of Paper Pulp [16][20]

WT (gm)	Moist (%)	Ash (%)	Volatile Material (%)	Free Carbon (%)	GVC Kcal/Kg
420	5.84	40.6	44.7	8.9	2372

Table 4 Ultimate Analysis of Paper Pulp [16] [20]

WT (gm)	C (%)	H (%)	N (%)	S (%)	O (%)
420	22.7	2.5	0.3	0.4	23.6

B. CrusherDust

Stone dust is a selective material that can be effectively used in construction as a replacement for natural sand [9]. This is a waste of composite crop availability. Stone dust is better suited for its economical nature and character than conventional sand for medium-sized concrete. The replacement of aggregate with stone dust can be compassed by 40% approximately, and this results in acceleration of compressive strength of concrete by 22% roughly [7]. This study examines the use of stone dust as a good mixing of concrete instead of a good mix of natural materials and improves pozzolan reaction, less compact compaction, and concrete strength [21].

III. METHODOLOGY

The research followed in this paper is based on the experimental analysis for obtaining sustainable concrete by incorporating waste materials in the mix. Therefore, to achieve this, paper pulp and crusher dust are considered a waste material, and it replaces cement and sand respectively. The comparison investigation is carried to examine the average compressive strength, split tensile strength, and slump values of newly investigated concrete with normal M_{20} concrete of grade. The first step followed in the research is testing of materials used in the preparation of concrete mix and the achieved values are shown in Table 5**.** The second step involves defining the percentage replacement of paper pulp and crusher dust by cement and sand respectively by deeply exploring peer-reviewed published research. Hereafter the assumed replacement of waste materials (P.P and C.D) are shown in the first column of Table *6* with sample name.

Table 5 IS code testing of materials for concrete mix

Sl. No	Test on Cement	IS Code	Value
1	Specific gravity	IS 2720 (part III) 1980	3.15
2	Fineness test	IS:4031(part I) - 1996	2.52%
3	Soundness test	IS:4031(part III) - 1996	6 mm
4	Standard consistency test	IS:4031(part IV) - 1996	31%
5	Initial setting time	IS:4031(part V) - 1996	28 min
6	final setting time	IS:4031(part V) - 1996	522 min

Table 6 Weight of materials for 1m^3 of concrete

Sample Name	Paper Pulp (P.P %) + Crusher dust (C.D %)	Cement (kg)	F.A (kg)	C.A (kg)	P.P (Kg)	C.D (Kg)	Water (Kg)	Slump (mm)
S-1	0% + 0%	394.320	620.750	1236.920	0.000	0.000	197.160	87.00
S-2	2.5% + 10%	345.030	620.750	1236.920	9.858	39.432	197.160	84.00
S-3	2.5% + 20%	305.598	620.750	1236.920	9.858	78.864	197.160	83.00
S-4	2.5% + 30%	266.166	620.750	1236.920	9.858	118.296	197.160	81.00
S-5	5% + 10%	335.172	620.750	1236.920	19.716	39.432	197.160	79.00
S-6	5% + 20%	295.740	620.750	1236.920	19.716	78.864	197.160	78.00
S-7	5% + 30%	256.308	620.750	1236.920	19.716	118.296	197.160	76.00
S-8	7.5% + 10%	325.314	620.750	1236.920	29.574	39.432	197.160	75.00
S-9	7.5% + 20%	285.882	620.750	1236.920	29.574	78.864	197.160	74.50
S-10	7.5% + 30%	246.450	620.750	1236.920	29.574	118.296	197.160	73.00
S-11	10% + 10%	394.320	620.750	1236.920	39.432	39.432	197.160	71.00

S-12	10% + 20%	276.024	620.750	1236.920	39.432	78.864	197.160	70.00
S-13	10% + 30%	236.592	620.750	1236.920	39.432	118.296	197.160	69.00
S-14	12.5% + 10%	305.598	620.750	1236.920	49.290	39.432	197.160	66.00
S-15	12.5% + 20%	266.166	620.750	1236.920	49.290	78.864	197.160	64.00
S-16	12.5% + 30%	226.734	620.750	1236.920	49.290	118.296	197.160	63.00

A. Design Mix for M20 grade of concrete

Procedure for concrete mix design calculation as per IS 10262-2009 based on strength, durability, workability, and economy [22] [23]. To produce concrete of required strength and properties, selection of ingredients and their quantity is to be found which is called concrete mix design. Proper mix design helps in clarifying the problem arises in concrete while placing or curing etc. As per IS456:2000, different grades of concrete are classified into M_5, $M_{7.5}$, M_{10}, M_{15}, etc.,whereas M stands for Mix, and the subscript of M stands for characteristic compressive strength (f_{ck}) of the concrete in N/mm_2 [24].

The average compressive strength is measured with cube specimens of dimension 150 mm × 150 mm × 150 mm cube in direct compression and the split tensile strength of concrete is measured with the help of cylindrical specimen cubes of 150 mm in diameter and 300 mm long [25] [23]. The design mix for M_{20} concrete used in this paper is 1:1.57:3.13, and details are shown in Table 7. The weight of different materials used in the mix design of $1m^3$ M_{20} grade of concrete using paper pulp and crusher dust are shown in Table 7.

Table 7 Mix Design for M_{20} grade of $1m^3$ concrete

Mix Design Calculation	Quantity
a) Volume of concrete =	1 m^3
b) Volume of entrapped air in wet concrete =	0.01 m^3
c) Volume of cement = [Mass of cement] / {[Specific Gravity of Cement] x 1000}	0.125 m^3
d) Volume of water = [Mass of water] / {[Specific Gravity of water] x 1000}	0.197 m^3
e) Volume of all in aggregate = [(a-b) - (c+d)]	0.668m^3
Mass of coarse aggregate = e × Volume of coarse aggregate × Specific gravity of coarse aggregate × 1000	1236.92 Kg
Mass of fine aggregate = e × volume of fine aggregate × Specific gravity of fine aggregate × 1000	620.75 Kg
DESIGN MIX (C : F.A : C.A) = (1 : 1.57 : 3.13)	

IV. RESULTS AND DISCUSSION

A. Slump Test

The standards IS: 1199 -1959 method is adopted in which the required apparatus are slump cone, non-porous base plate, measuring scale, and temping rod [26]. The shape of the mold is a frustum of a cone, and a specific dimension is, height 300 mm, bottom diameter 200 mm, and top diameter 100mm [26]. Further, the dimension ofthe tamping rod of steel is 16 mm diameter and 600 mm long [26]. The slump values of samples show non-linear declination as the paper pulp is increasing from 2.5% to 12.5%. The highest slump is recorded for S-1 (normal mix) and the lowest is recorded for S-16, the numeric values, and the trend of samples is shown in Figure*1*.

B. Average CompressiveStrength

Samples (S-1…S-16) as per IS: 516-1959 are casted considering mix design as 1:1.57:3.13 [25]. Total of 48 samples are cast of cube size 150 mm × 150 mm × 150 mm including normal mix and newly formed samples as shown in Table 8. As seen after Compression Testing Machine (CTM), the samples S-2…S-8 shows average compressive strength higher than S-1 (normal mix), and the highest strength is recorded for the S-5 sample.

Afterward, the strength of samples S-9…S-16 starts decreasing when compared to S-1 (normal mix), and the lowest strength is recorded for the S-16 sample. The detailed results of all the samples are shown in Table 8**,** and the trend chart is shown in Figure 2 below.

C. Split Tensile Strength

Samples (S-1…S-16) as per IS: 5816-1999 are cast considering mix design as 1:1.57:3.13 [23]. A total of 48 samples are cast of cylindrical size 150 mm in diameter and 300 mm in length, including normal mix and newly formed samples as shown in Table 9. The results seen from the compression testing machine suggests that samples S-2…S-8 shows split tensile strength higher than S-1 (normal mix), and the highest strength is recorded for S-5 sample. Afterward, the strength of samples S-9…S- 16 starts decreasing when compared to S-1 (normal mix), and the lowest strength is recorded for the S- 16 sample. The detailed results of all the samples are shown in Table 9**,** and the trend chart is shown in Figure 3.

Table 8 Average compressive strength at 7th and 28th day

Sample Name	P.P (%) + C.D (%)	Avg. Comp Strength at 7th (N/mm^2)	Avg. Comp Strength at 28th (N/mm^2)
S-1	0% + 0%	17.56	27.01
S-2	2.5% + 10%	18.63	28.66
S-3	2.5% + 20%	18.89	29.06
S-4	2.5% + 30%	18.98	29.65
S-5	5% + 10%	19.84	31.00
S-6	5% + 20%	18.20	28.43
S-7	5% + 30%	17.78	27.79
S-8	7.5% + 10%	17.37	27.14

S-9	7.5% + 20%	17.33	26.85
S-10	7.5% + 30%	16.81	26.04
S-11	10% + 10%	13.85	21.46
S-12	10% + 20%	13.28	20.57
S-13	10% + 30%	12.72	19.70
S-14	12.5% + 10%	11.98	18.82
S-15	12.5% + 20%	10.90	17.13
S-16	12.5% + 30%	10.20	16.02

Table 9 Split Tensile Strength at 7th and 28th day

Sample Name	P.P (%) + C.D (%)	Split tensile Strength at 28th (N/mm^2)	Split tensile Strength at 28th(N/mm^2)
S-1	0% + 0%	1.95	3.00
S-2	2.5% + 10%	2.07	3.18
S-3	2.5% + 20%	2.10	3.23
S-4	2.5% + 30%	2.14	3.29
S-5	5% + 10%	2.22	3.44
S-6	5% + 20%	2.04	3.16
S-7	5% + 30%	2.00	3.09
S-8	7.5% + 10%	1.95	3.02
S-9	7.5% + 20%	1.93	2.98
S-10	7.5% + 30%	1.87	2.89
S-11	10% + 10%	1.45	2.29
S-12	10% + 20%	1.45	2.29
S-13	10% + 30%	1.39	2.19
S-14	12.5% + 10%	1.33	2.09
S-15	12.5% + 20%	1.21	1.90
S-16	12.5% + 30%	1.13	1.78

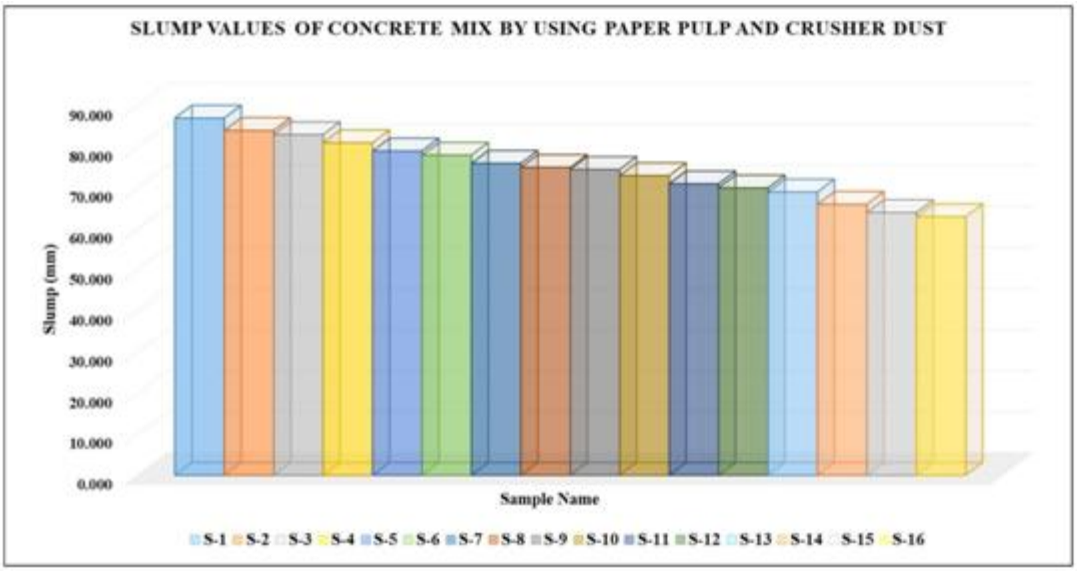

Figure 1 Trend chart of slump values for M_{20} concrete

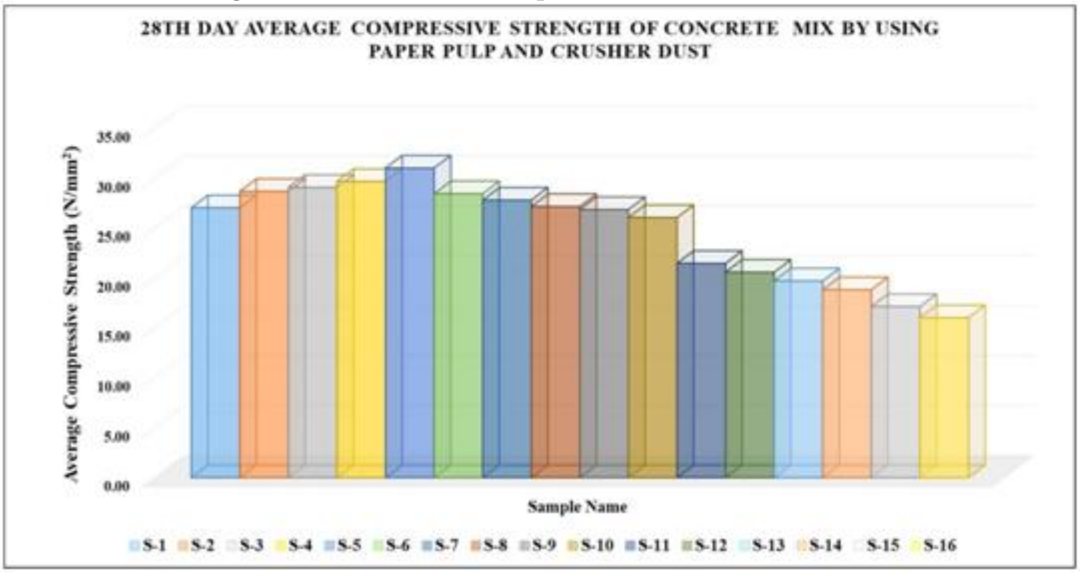

Figure 2 Trend chart of Average compressive strength at 28th day of M_{20} concrete

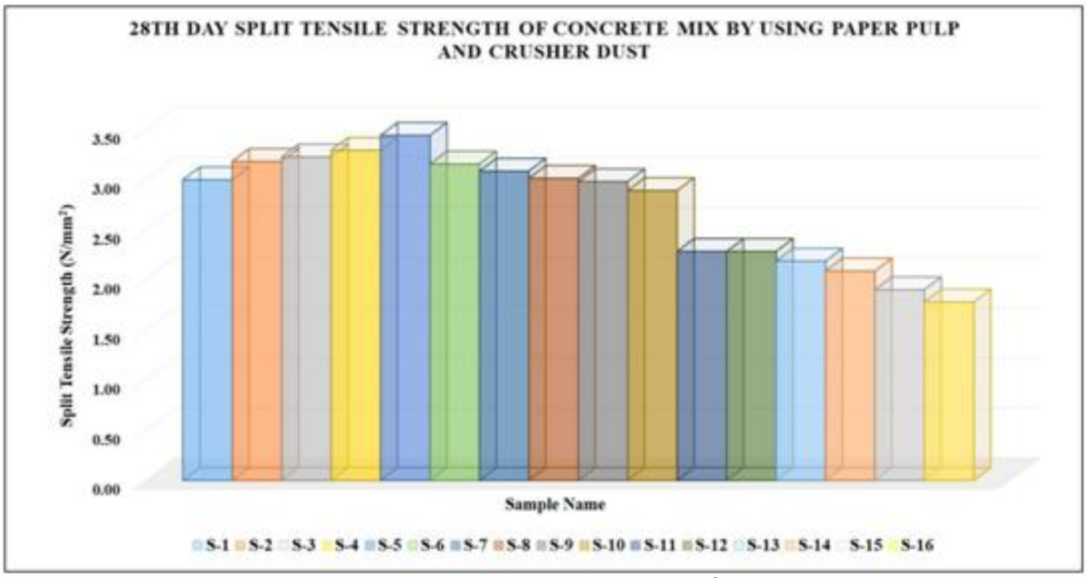

Figure 3 Trend chart of split tensile strength at 28th day of M_{20} concrete

V. CONCLUSION

The sustainable concrete obtained after adding paper pulp and crusher dust in the mix design of M20 concrete shows tremendous results in terms of strength and workability. As noticed, the results of average compressive strength and split tensile strength of samples (S-1…S-16) varies according to the percentage of paper pulp and crusher dust.

The workability of normal mix sample S-1 is observed 87mm, and afterward, the slump value keeps decreasing with a slight difference. The lowest slump observed is 63mm for sample S-16.

The average compressive strength when compared to normal mix sample S-1(P.P-0% and C.D-0%,27.01 N/mm2) is enhanced by almost 14% in sample S-5 (P.P -5% and C.D -10%, 31 N/mm2), and a reduction of 40% is observed in sample S-16 (P.P -12.5% and C.D -30%, 16.02 N/mm2). The trend observed in Figure 2 and Table 8 states that the average compressive strength of samples (S- 2…S-5) is greater than the normal mix sample (S-1) and afterward the samples (S-6…S-16) show a negative trend. Hence the optimum percentage of

P.P and C.D to obtain sustainable concrete by using waste materials (P.P and C.D) is for sample S-5. It is advised after the experimental investigation that the promotion of such a concrete mix must be enhanced.

Similar observations like average compressive strength are seen for split tensile strength, and the results shown in Table 9 verifies it. When compared to normal mix sample S-1 (P.P-0% and C.D-0%, 3.00 N/mm2), the results of split tensile strength is enhanced by almost 14% in sample S-5 (P.P -5% and C.D -10%, 3.44 N/mm2), and a reduction of 40% is observed in sample S-16 (P.P - 12.5% and C.D -30%, 1.78%). The trend observed in Figure 3 and Table 9 states that the average compressive strength of samples (S-2…S-5) is greater than the normal mix sample (S-1) and afterward the samples (S-6…S-16) shows a negative trend. Hence the optimum percentage ofP.P and C.D to obtain sustainable concrete by using waste materials (P.P and C.D) is for sample S-5.

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