Partial Replacement of Fine Aggregate by Waste Paper Sludge in Concrete

Anuradha Kadavkar[1], Dr. G.D. Awchat[2]
Department of Civil Engineering
[1] M.Tech (Structure) Student,Gurunanak institute of Technology, Nagpur, India
[2] Associate Professor,Gurunanak institute of Technology, Nagpur, India

Abstract*-The rapid increase in construction activities leads to scarcity of conventional construction materials such as cement, fine aggregate and coarse aggregate. Researchers are being conducted for finding cheaper materials. In India, there are many industries producing large amount of effluent treatment paper waste sludge which leads in problems of disposal. In the Pulp and Paper Industry several types of solid wastes and sludge are generated. Solid waste is mainly produced from pulping, deinking processes and wastewater treatment. The waste generation is strongly affected by the production process and wastewater treatment technologies. Paper manufacturing is a highly capital, energy and water intensive industry. In India, around 905.8 million m3 of water is consumed and around 695.7 million m3 of wastewater is discharged annually by this sector. The amount of waste generated in paper production varies greatly within different regions, because of different recycling rates. The purpose of this study is to find an alternate source for Fine aggregate, cement and as an admixture. In this project concrete was tested with w/c ratio of 0.45.*

Keywords-Paper waste sludge, concrete, admixture, w/c ratio, deinking processes.

I. INTRODUCTION

"Environment" is defined as the sum total of water, air and land and the inter relationships which exists among and between water, air and land, and human beings, other living creatures, plants, micro-organisms and property.

At present, the disposal solution employed is land filling even though the paper sludge is a decomposable organic material. However, the volume of paper sludge to be disposed of remains considerably high and become less feasible in recent years as environmental concerns have lead to rapidly increasing costs. Due to the limited landfill space available and stringent environmental regulations, many paper pulps are attempting to develop efficient, economic and environmental sound alternatives for utilizing this waste paper sludge.

Therefore, the civil engineers have been challenged to convert this paper sludge, in general, to useful building and construction materials. Utilization of paper sludge for construction shall not only solve waste problems, but also provide a new resource for construction purposes. Concrete is the most used construction material in the industrialized countries. However, the concrete production needs natural resources (water and aggregates) and cement whose production is costly due to the energy required. In order to reduce the use of natural content, sludge from water treatment plant is used for concrete production as fine aggregate. This sludge has disposal problems in order to reduce that reuse of that resources are about to tested with different percentage of replacement. This may drastically reduce the sludge content and even the cost of concrete. Sludge is a product which is obtained during the treatment of wastewater. The characteristic of sludge differ upon the region and the method of treatment. Sludge is formed after undergoing various steps such as stabilization, composting, anaerobic digestion, and thickening, dewatering and drying. This sludge contains maximum amount of nitrogen content and so it is majorly used for agricultural purpose.

II. LITERATURE REVIEW

I. Dibas et al. (2014) investigated recycled aggregate concrete with silica fume for compressive strength. Two types of recycled aggregates were used, composed of concrete, tiles and bricks. The replacement levels of aggregates were 30% and 40%, later both types were used simultaneously taking replacement of 70%. Silica fume replaced was 5% and 10% by weight of cement. The results showed that impurities in recycled aggregates can reduce the effect of silica fume. Despite that concrete containing separate recycled aggregates exhibited good results using 5% and 10% silica fume when compared with traditional concrete.

II. Ismail and Ramli (2013) pre-soaked the RCA (recycled coarse aggregate) in acid of different morality and studied the slump values of both treated and untreated RCA, no significant difference in the slump values was observed. It has been reported that angular and rough surface of RCA decreases the slump values as compared to natural aggregates concrete.

III. Surya et al. (2013) produced five different concrete mixes with and without class F Fly ash. Three mixes containing recycled aggregate at 50%, 75% and 100% replacement of natural aggregate were prepared containing fly ash, and two natural aggregate concrete mixes with and without fly ash. Recycled aggregates were generated by crushing waste dump of lab samples. Water-cement ratio was kept constant at 0.4. The splitting tensile strength exhibited by recycled aggregate concrete was better than traditional concrete. In case of recycled aggregate concrete the failure pattern was through transition zone and aggregates. The concrete containing 100% recycled aggregate exhibited maximum splitting tensile strength. The transition zone of recycled aggregate concrete improved due to addition of fly ash making its strength parallel or greater than control mixture.

IV. Kou and Poon (2013) presented long term splitting tensile strength of recycled aggregate concrete prepared with incorporation of fly ash. The recycled aggregate concrete was prepared by using 25%, 35% and 55% fly ash whereas recycled aggregate used were substituted as 0%, 50% and 100%. Two types of curing conditions were imposed water and air curing. At 28 days the splitting tensile strength of control mixture was higher than the concrete incorporating recycled aggregates. However, comparison of the longer duration test results shows continuous and significant improvement in the splitting tensile strength of recycled aggregate concrete. The values of concrete mixtures prepared with 100% recycled aggregates were higher than traditional concrete. Moreover, the splitting tensile strength of concrete mixtures exposed to air curing was lower than the corresponding concrete mixtures with standard water curing.

V. Saikia and Brito, (2012) observed the incorporation of any type of plastic aggregate lowers the splitting tensile strength of concrete. The causes for the reductions observed in splitting tensile strength reported in various references were similar to those used to explain the decrease in compressive strength due to the incorporation of plastic aggregate.

III. METHODOLOGY

It is the method followed to perform the experiment. In this section we have made step wise procedure to perform experiment which is briefly described as follows:

1) Mix designed
2) Batching
3) Experimental programmed of casting
4) Mixing
5) Compaction
6) Curing
7) Testing

3.1 Mix design Mix design is the process of selection of suitable ingredients of concrete and to determine their properties with object of producing concrete of certain maximum strength and durability, as economical as possible. The purpose of designing is to achieve the stipulated minimum strength, durability and to make the concrete in the most economical manner.

3.2 Mix combinations model

Concrete mixes were produced in the laboratory: P-100 (Control Mix)**,** PF-5-95, PF-15-85, PC-5-95, PC-10-90, PA-0.4 and PA-0.8. Various percentages of paper sludge replacement proportion to fine aggregate, cement and as admixture in concrete are show in Table 1 & 2.

3.3 Mix design (as per IS10262:2009 & IS456:2000**)** Mix design is the process of selection of suitable ingredients of concrete and to determine their properties with object of producing concrete of certain maximum strength and durability, as economical as possible. The purpose of designing is to achieve the stipulated minimum strength, durability and to make the concrete in the most economical manner.

Table no1: - 8 Mix combinations model

P-100	**Control Mix**
PF-5-95	5% paper sludge replacement of fine aggregate (95% fine aggregate + 5% PMS)
PF-15-85	15% paper sludge replacement of fine aggregate (85% fine aggregate + 15% PMS)
PC-5-95	5% paper sludge replacement of cement (95% cement + 5% PMS)
PC-10-90	10% paper sludge replacement of cement (90% cement + 10% PMS)
Percentages	0.4% paper sludge as admixture in concrete
40-52	0.8% paper sludge as admixture in concrete

Table no2-:9 Stipulations for proportioning

A	Grade designation	M 25

B	Type of cement	PPC grade I conforming IS 8112
C	Maximum normal size of aggregate	10 mm
D	Minimum cement content	240 Kg/m^3
E	Maximum water cement ratio	0.60
F	Workability	50 to75 mm
G	Method of concrete placing	Manually
H	Maximum cement content	450 Kg/ m3
I	Degree of supervision	Good
J	Admixture	PMS
K	Type of aggregate	Crushed angular aggregate

3.4 Characteristic Strength

The compressive strength of concrete is given in terms of the characteristic compressive strength of 100 mm size cubes tested at 28 days (fck). The characteristic strength is defined as the strength of the concrete below which not more than 5% of the test results are expected to fall. This concept assumes a normal distribution of the strengths of the samples of concrete.

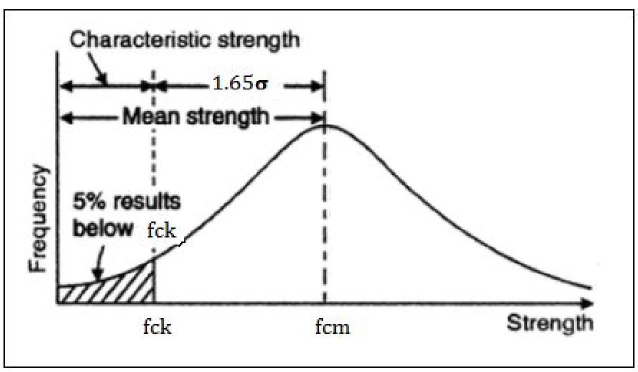


Fig.2: Normal Distribution curve on test specimens for determining compressive strength

Target strength for mix proportioning

f'ck = fck+1.65 s

Where,***f'ck*** = Target Average compressive strength of 28 Days

fck = compressive strength of 28 Days

s= Standard deviation Standard deviation,

s =5 n/mm2.

Therefore, target strength = 25 + 1.65 x 4 =31.6N/mm2.

Selection of water-cement ratio
From table 5, IS 456: 2000 for RCC structure,
Maximum water-cement ratio = 0.60 Based on experience,
Adopt water-cement ratio as 0.45, 0.45 < 0.60, Hence o.k.

Selection of water content
From table 2, as per IS10262:2009

Maximum water content =208 liters (for 25 to 50 mm slump range)

And for 10mm aggregate
Estimated water content for 75 mm slump as per IS10262:2009 = 208 + (208 x 5%) =219 LTR
Calculation of cement content
Water cement ratio = 0.45 From table no 5,
IS code 456 Cement content = 219 ÷ 0.45 = 486.66 Kg/m3
Adopted cement content is 443 Kg/m3 (450 < 487 > 240) Kg/m^3

Proportion of volume of coarse aggregate and fine aggregate content

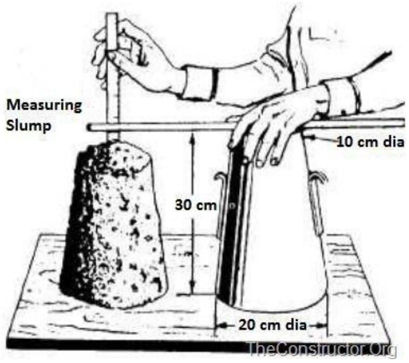
In the present case water-cement ratio is 0.45.Therefore volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by 0.05, the proportion of volume of coarse aggregate is increased by 0.02 (at the rate of ± 0.01 for every ± 0.05 change in water-cement ratio).

Therefore, corrected proportion of volume of coarse aggregate,
For the water-cement ratio of 0.45 = 0.61.
The Volume of fine aggregate content = 1 − 0.61 = 0.39.

IV. TESTING OF SPECIMEN

1. Workability test

According to IS: 1199, workability is defined as that property of concrete which determines the amount of useful internal work necessary to produce complete compaction. For determining the workability of concrete slump test was adopted. Slump test is the most commonly used method for measuring consistency of concrete which can be employed either in laboratory or at site of work. It is not a suitable method for very wet or very dry concrete. However, it is used conveniently as a control test and gives an indication of the uniformity of concrete from batch to batch. Slump test was conducted according to IS: 1199-1959. The mould for the test specimen shall be in the form of the frustum of a cone having the following internal dimensions:
Bottom diameter = 20 cm
Top diameter = 10 cm
Height= 30 cm



Slump mould

The internal surface of the mould was thoroughly cleaned and freed from superfluous moisture and any set concrete before commencing the test. The mould was placed on a smooth, horizontal, rigid and non-absorbent surface, the mould being firmly held in place while it is being filled. The mould was filled in four layers, each approximately one-quarter of the height of the mould. Each layer was tamped with twenty-five strokes of the rounded end of the tamping rod. The strokes were distributed in a uniform manner over the cross-section of the mould. After the top layer was been rod, the concrete was struck off level with a trowel or the tamping rod, so that the mould is exactly filled. The mould was then removed from the concrete immediately by raising it slowly and carefully in a vertical direction. This allows the concrete to subside and the slump was measured immediately by determining the difference between the height of the mould and that of the highest point of the specimen being tested.

2. Compressive Strength test

The compressive strength of concrete is one of most important properties of concrete in most structural applications. For compressive strength test, cube specimens of dimensions 150 × 150 × 150 mm were cast for M25 grade of concrete. The specimens were remolded after 24 hours of casting and were transferred to curing tank wherein they were allowed to cure for 28 days. After curing, these cubes were tested on Compression Testing Machine (capacity 2000 KN) as per IS: 516-1959. The failure load was noted. In each category three cubes were tested and their average value is reported. The compressive strength was calculated as follows,

Compressive strength (MPa) = Failure load / cross sectional area.

Average of three value have taken as representative of the batch. The individual variation was not more than ±15% average otherwise repeated tests would have been made.

Compressive Strength test Reading

Specimen identifica tion	**Compressive strength (MPa)**		**Compressive strength (MPa)**		**Compressive strength (MPa)**	
	7 Days	**Avg**	**14 Days**	**Avg**	**28 Days**	**Avg**
Control Mix	25.28 26.79 25.57	25.87	29.07 30.27 29.66	29.6 7	35.13 34.34 33.14	34.17
PF-15-85	22.76 20.88 19.28	20.97	26.17 24.01 21.79	23.9 9	35.13 33.52 37.38	35.34
PF-5-95	21.23 18.41 20.28	20.11	24.84 20.80 23.31	22.9 9	32.92 31.44 30.00	31.53
PC-5-95	21.84 17.45 20.25	19.85	24.67 20.94 24.00	23.2 3	32.47 30.52 29.92	30.96
PA-0.8	17.45 17.39 17.93	17.54	19.36 20.86 20.61	20.2 8	31.30 27.35 29.68	29.44
PA-0.4	15.85 17.11 17.02	16.66	17.75 20.18 20.25	19.4 2	27.74 30.64 25.26	27.88
PC-10-90	12.73 13.33 13.53	13.2	15.19 16.13 15.70	15.6 7	18.24 18.75 17.89	18.29

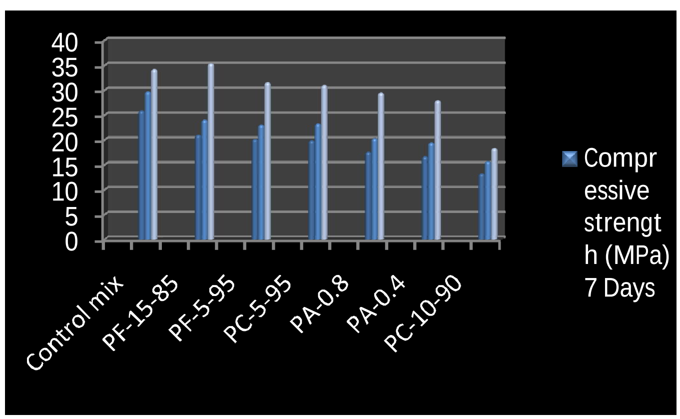


Figure 4.4: Comparing compressive strength.

3. Split tensile strength test

Tensile strength can be determined by either direct methods or indirect methods. The direct method has difficulties related to holding the specimen properly in the testing machine without introducing stress concentration, and in application of uniaxial tensile load which is free from eccentricity to the specimen. Hence indirect tests are generally adopted. The split tensile strength test was conducted as per IS 5816:1999. For split tensile strength test, cylinder specimens of dimension 100 mm diameter and 200 mm length were cast. The specimens were remolded after 24 hours of casting and were transferred to curing tank wherein they were allowed to cure for 28 days. These specimens were tested under the compression testing machine by applying a compressive load across the diameter till the cylinder splits. The failure load was recorded. In each category three cylinders were tested and their average value is reported. Split tensile strength was calculated as follows:

Split Tensile strength (MPa) = $2P / \pi DL$

Where,

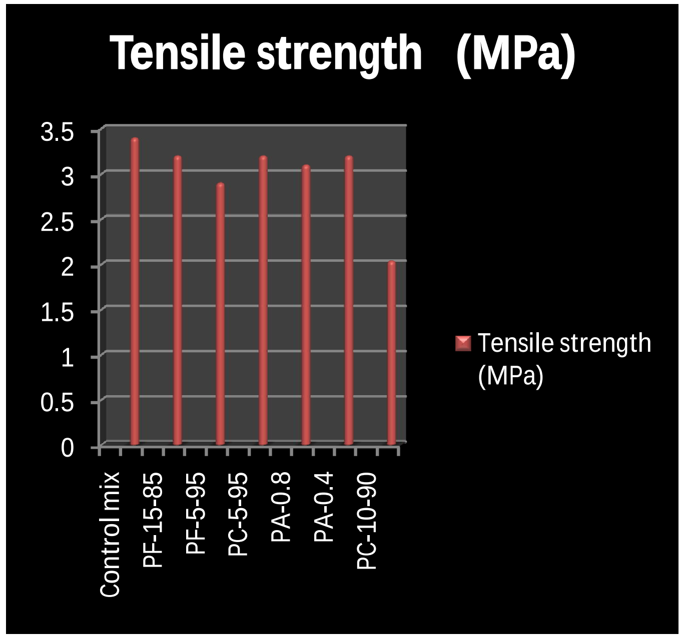
P = failure load,

D = diameter of cylinder,

L = length of cylinder.

Split tensile strength test reading

Sr. No.	Specimen identification	Tensile strength (MPa)	
		28 days	Average
1	Control mix	3.53 3.34 3.28	3.4
2	PF-15-85	3.19 3.1 3.1	3.2
3	PF-5-95	2.96 2.84 2.8	2.9
4	PC-5-95	3.22 3.00 3.18	3.2
5	PA-0.8	2.97 3.03 3.20	3.1
6	PA-0.4	3.33 3.1 3.00	3.2
7	PC-10-90	2.19 1.793 2.13	2.2



Graphical arrangement of tensile strength

4. Flexural strength test:

For flexural strength test beam specimens of dimension 150 × 150 ×700 mm were cast. The specimens were remolded after 24 hours of casting and were transferred to curing tank wherein they were allowed to cure for 28 days. These flexural strength specimens were tested under two point loading as per I.S. 516-1959, over an effective span of 600 mm divide into three equal parts and rest on Flexural testing machine. The load in normally increased and failure load in noted at cracking of beam specimen. In each category two beams was tested and their average value is reported. The flexural strength was calculated as follows.

Flexural strength (F_B) = pl/bd^2

When,

1. a > 20.0cm for 15.0cm specimen or
2. a > 13.0cm for 10cm specimen)

OR,

Flexural strength (F_B) = $3pa/bd^2$

When,

1. a < 20.0cm but > 17.0 for 15.0cm specimen or
2. b< 13.3 cm but > 11.0cm for 10.0cm specimen.)

Where,

a = distance of crack from any support

b = width of specimen = 150 mm

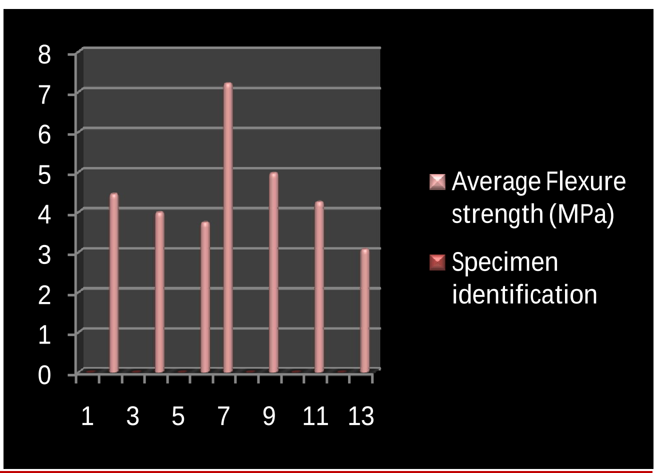
d = failure point depth = 150 mm

l = supported length = 600 mm

p = max. Load (kg) or Failure load

Flexural strength test readings

Sr. No.	Specimen identification	Flexure strength (MPa)	
		28 days	Average
1	Control mix	4.22 4.3 4.8	4.45
2	PF-15-85	4.76 3.02 4.17	3.99
3	PF-5-95	3.64 4.22 3.35	3.74
4	PC-5-95	7.18 7.49 7.08	7.21
5	PA-0.8	5.69 3.77 5.46	4.97
6	PA-0.4	3.2 4.5 5.07	4.25
7	PC-10-90	2.95 3.39 2.86	3.07



Graphical representation of flexural strength

V. CONCLUSION

Sludge can be used as an effective replacement of fine aggregate and it can be replaced with 20% in concrete. The compressive strength is increased with the addition of sludge; Flexural strength is also increased when compared with the control mix. The maximum compressive strength and flexural strength value obtained for OPC 43 grade cement. The workability of the mix containing Paper sludge shows an inverse relation with the increase of replacement. Replacement. The compressive strength of 0.4% replaced concrete has 99.14% of compressive strength of ordinary concrete and compressive strength of 10%, 15% replaced mix have attained 97.66% and 92.59% of strength of reference mix respectively. The split tensile and flexural strength of 5% replaced concrete are less but approximately similar to the ordinary mix.

REFERENCES

[1] A. Nasser and S. Afifi, "Assessment of existing and future sewage sludge characterization in Gaza Strip Palestine," Int. J. Environment and Pollution, Vol. x, Nos. x, 2006.

[2] M. H. Al-Malack, N. S. Abuzaid, A. A Bukhari, and M. H. Essa, "Characterization, utilization, and disposal of municipal sludge: the state of the art,"

[3] E. Levlin, "Sustainable sludge handling," Report No. 2, Proceedings of a Polish-Swedish seminar, KTH, Stockholm, May 30, 1997, Joint Polish - Swedish Reports, Div. of Water Resources Engineering, Royal Institute of Technology, Stockholm, ISRN KTH/AMI/REPORT 3045-SE, ISBN 91- 7170-283-0.

[4] D. E. Meeroff and F. Bloetscher, "Sludge management, processing, treatment and disposal," Florida water resources journal, November 1999.

[5] Dhinesh A, (2014), Priliminary studies of common effluent treatment waste sludge in manufacturing of solid block, SJET.

[6] Alqedra, M., Arafa, M., Mattar, M. (2011) Influence of low and high organic wastewater sludge on physical and mechanical properties of concrete mixes. Journal of Environmental Science and Technology, 4 (4), 354-365.

[7] Etxeberria M., Pacheco C, Meneses JM, Berridi I. (2010) Properties of concrete using metallurgical industrial by-products as aggregates. Construction and Building Material, 24, 1594–600

[8] Metcalf & Eddy, Inc. (2002). Wastewater Engineering: Treatment, Disposal, and Reuse, 4th ed. George Tchobanoglous and Franklin L. Burton, 2002, Mcgraw-Hill.

[9] IS: 10262-2009, Concrete Mix Proportioning- Guidelines, Bureau of Indian Standards, New Delhi, 2009.

[10] S Rajendra Prasad (2011), Article in a regular journal, Intl. J. of EarthSciences and Engineering, ISSN 0974-5904, Volume 04, No 06, SPL, pp. 959964.

[11] Raheem, A. A.; Oyebisi, S. O.; Akintayo, S. O. and Oyeniran, M. I. (2010), "Effects of admixtures on the properties of corn cob ash cement concrete", Leonardo Electronic Journal of Practices and Technologies, Vol. 16, pp.13 – 20.

[12] Lynn, C., Dhir, R., Ghataora, G., and West, R. (2015). "Sewage sludge ash characteristics and potential for use in concrete." Construction and Building Materials, 10.1016/j.conbuildmat.2015.08.122, 767-779.

[13] Patel H., Pandey, S. (2011) Evaluation of physical stability and leachability of Portland Pozzolona
[14] Alqedra, M., Arafa, M., Mattar, M. (2011) Influence of low and high organic wastewater sludge on physical and mechanical properties of concrete mixes. Journal of Environmental Science and Technology, 4 (4), 354-365.
[15] Bureau of Indian standards IS 10262:2009; Mix design of concrete, New Delhi, India.
[16] Bureau of Indian standards IS 516: 1959; Methods of tests for Strength of concrete, New Delhi, India.
[17] Bureau of Indian standards IS 5816: 1999: Splitting tensile strength of concrete - method of test, New Delhi, India.