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Waste Paper Sludge Ash and Crushed Rock Sand Based on Concrete with Smart Materials - A Review

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Abstract: In the construction sector concrete is used 327 million metric tons in India during the year 2020 and it requires a large quantity of cement and aggregates. Cement producing industry is one of the carbon dioxide emitting sources besides deformation fuels and concrete is one of the largest consumes of natural resources materials. The cement industry produces about 7% of carbon dioxide emissions to the earth's atmosphere. As natural resources depleting due to excavation of river sand from natural resources is a serious problem to the environment. On the other side waste and by products from several industries are finding their way as alternative binding materials to prepare concrete. This paper presents the review of some research papers which uses locally available waste paper sludge ash and crushed rock sand replacing cement and fine aggregate in concrete.

Keyword: Crushed rock sand, Environment pollution, Paper sludge.

I INTRODUCTION

Concrete is a basic need in the construction sector. Nowadays due to fast economic growth, the rapid development of urbanization and the prosperity demand for construction activities increased. Therefore the demand for construction raw materials like cement, sand, aggregate also increased. To reduce cost and environmental effects needs an alternative source for full filling the demand of sustainable construction materials. Wastes and by-products from several industries are finding their way as substitutes or alternative materials to prepare concrete. Landfill disposal is resulting in high costs and potential environmental problems. There is a need to develop alternative binding material for concrete using paper sludge ash and crushed rock sand and minimize the natural resource materials used in the construction sector. The following sections 1.1 to 1.3 discussed in paper sludge ash and crushed sand and their properties can be utilized in concrete structures.

1.1 Paper sludge

Wastepaper sludge is the primary waste from the paper industry. Paper mill residual solids also called sludge is composed mainly of cellulose fibres, moisture and paper making fillers like kaolinite clay and calcium carbonate, silica, magnesium, calcium chloride.

The paper sludge can be minimizing the demand for cement and reduce the cost of construction Abhishek G L [23]. About 300 kg of sludge is produced for each tonne of recycled paper.

This is a relatively large volume of sludge produced each day that makes serious disposal problems as paper mill sludge is bulky. It was originally introduced as artificial pozzolana.

When pozzolanic materials are incorporated into concrete, the silica present in these materials reacts with the calcium hydroxide released during the hydration of cement and forms additional calcium silicate hydrate, which improves mechanical properties but only up to a certain extent Cherian V et al [4].

The dry paper sludge was calcined in a laboratory electric furnace.

The heating rate was 20 ºC/min. and taking into account economic and energetic aspects, activation conditions, at lab scale, were established in the range from 650ºC to 700ºC. After the thermal treatment, the calcined product was ground and sieved to obtain particles below 45 μm Garcı´a R et al [8].

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Fig.1 shows the typical composition of paper sludge.

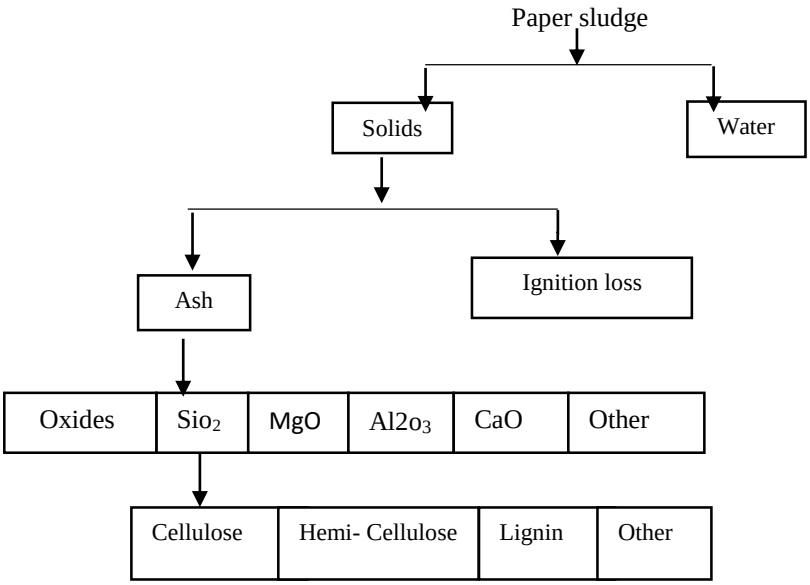

Fig.1 A Typical composition of paper sludge

1.2 Characteristics of Paper Sludge

Section 1.2.1 through 1.2.3 reported based on physical, chemical and mineralogical properties of paper sludge

1.2.1 Physical properties

Paper mill sludge is composed of mineral fillers, small cellulose fibres, water, inorganic salts and organic compounds. It was then sun-dried and incinerated to convert it into ash. The ash was sieved through a 90 micron Indian Standard sieve. The specific gravity of waste paper sludge ash was found to be 2.6 Sajad A, et al [3]. The specific surface area of WPSA 4010 (g/cm^2), Density is 2.93 (g/cm^3) and the specific gravity of waste paper sludge ash was found to be 3.1[9].

1.2.2 Chemical properties

The principal constituents present in Waste Paper Sludge Ash (WPSA) are lime (CaO) and silica (SiO_2). The amounts of the other major elements were low (less than 2%), except for MgO (4%). Therefore it contains also Aluminum trioxide(Al_2O_3), Ferric trioxide(Fe_2O_3) ,Magnesium oxide(MgO), Sulphate(SO_3), Potassium oxide(K_2O) etc. During incineration, organic compounds are burned at temperatures of around 350 to 500°C, whereas mineral fillers and inorganic salts are transformed into the corresponding oxides at higher temperatures (>800°C) Shishir Kumar et al [14]. Table 1 shows the typical chemical composition of WPSA and OPC reported in the literature [9, 18, 19, 20, 21, and 20].

Table 1: A typical chemical composition of activated waste paper sludge ash (WPSA) and ordinary Portland cement (OPC).

Oxide Composition %	CaO	SiO_2	Al_2O_3	Fe_2O_3	K_2O	MgO	TiO_2	P_2O_5	MnO	Na_2O	So_3	LOI
Vegas et al., [9] WPSA	31.4	30.20	18.0	0.70	0.32	3.70	0.35	0.19	-	0.21	0.27	14.53
Frias et al., [18] WPSA	40.21	22.32	14.55	0.56	0.37	2.35	0.26	0.18	-	0.09	0.32	18.52
Ngo et al., [19] WPSA *	44.55	27.80	13.79	4.94	3.92	0.28	0.73	–	0.03	0.33	-	-
Fauzi et al., [20] WPSA *	62.4	23.3	5.3	0.8	0.4	2.5	0.5	0.5	0.5	0.4	0.6	4.5
Segui et al., [21] WPSA	45.5	28.0	13.2	1.3	0.7	4.0	0.7	0.4	0.1	0.4	1.3	5.7
Fauzi et al., [20] OPC*	64.6	21.3	5.6	3.4	0.2	2.1	0.1	0.1	0.1	2.1	0.1	0.6

***Temperature are not mentioned, Temperature reported by [9] 650^{0}C, [18] 700^{0}C, [21]850^0 C**

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1.2.3 Mineralogical properties

XRD Techniques is generally adopted for the mineralogical properties of waste paper sludge. The material is essential amorphous silicates and Aluminates, mainly gehlenite (2CaO, $Al_2O_3SiO_2$) and melilite ($8CaO3Al_2O_3MgO_5SiO_2$), is responsible for the pozzolanic reaction. The mineralogical consists of two parts as inorganic and organic. The inorganic part is a crystalline mineral compound, kaolinite (Al_20_3, $2SiO_2$, $2H_2O$), calcite ($CaCO_3$) and the Organic part is cellulose ($C_{12}H_{20}O_{10}$). The mineralogical composition of paper sludge is presented in Table 2.

Table 2: Mineralogical composition of dried de-inking paper sludge percentage by mass reported in the literature.

	Organic matter	Quartz	Talc	Kaolinite	Calcite	Others
Vegas et al., [9]	32.10	1.71	6.85	20.83	35.30	1.71
Garcia R et al.,[8]	29.0	2.0	2.0	21	35	11
Frias et al., [25]	32.3	3.3	5.0	13.7	45.3	-

1.3 Crushed Rock Sand

Natural sand is one of the major components used in CVC, it is a most expensive and scarcity problem. The use of crushed rock sand as an alternative material for the construction industry for fine aggregate and reduce the cost of construction and degradation of natural river beds. The crushing of quarry, coarse aggregate results in a fine particle called screening sometimes also referred to as manufactured sand. The production of artificial sand generally crushing, screening and possibly washing to separate the discrete, silt and clay particles. The crushed aggregate particles are used as fine aggregate to replace the natural river sand to achieve economic, desirable strength and properties of the concrete.

1.3.1 Characteristics of Crushed Rock Sand

The physical and chemical properties such as size, shape, colour and surface texture of particles depend upon the type of rocks and its origin of source Swapnil S [14]. Adopt crushed rock sand as a replacement for fine aggregate. Crushed rock sand is artificial sand it contains a large number of angular particles with more surface texture and flatter than natural sand. The artificial crushed rock sand is satisfied the requirements and characteristics and replace the natural sand for making concrete is eco-friendly in an economic way [10]. The below table shows the properties of physically crushed rock sand and natural river sand.

Table 3: Physical properties of crushed rock sand and natural river sand

	Specific gravity of sand	Fineness Modulus	Density	Water absorption	Grading
Yajurved et al., [11]	2.57	2.75	1971 Kg/m^3	2.26%	Zone II
Balamurugan et al., [24]	2.57	2.41	1850 Kg/m^3	4.2%	Zone II
Nagendha et al., [26]	2.82	2.84	1750 Kg/m^3	5.6%	Zone II
Nagendha et al., [26] *	2.60	2.89	1460 Kg/m^3	6.5%	Zone II

***Properties of natural sand**

II LITERATURE REVIEWS

Jayeshkumar p et al (2013) conducted an innovative use of paper industry waste in design mix concrete. The cement is partially replaced by waste paper sludge ash in the range of 0%, 10%, 20%, 30% and 40% by weight for design mix of M25 and M40 grade of concrete. The test is conducted to find out the mechanical properties of the compressive and split tensile strength of concrete. The 10% use of waste paper sludge as his strength increased compared to conventional concrete. They concluded that paper sludge can be utilized in the concrete mix as a good substitute for cement.

Was conducted [2] an application of paper waste in cement concrete. The cement is substitute to WPSA with 0%, 10%, 15%, & 20% for the design of M25 grade of concrete. The 15% use of WPSA strength gradually increased compared to normal conventional concrete. The slump and water absorption of design mix concrete decreased with the addition of waste paper sludge ash are increased. He concluded that WPSA could be used to replace cement in general concrete structures.

Sajad A et al study the concrete involving utilization of waste paper sludge ash as a substitute to cement. They have reported that the use of WPSA was partially replaced as 0 to 20% at an increment of 5% with cement. For the design of M-25 mix grade of concrete to evaluate the compressive strength, tensile strength and water absorption of concrete.

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The cement is replaced by WPSA at 5% by weight nearly 15% increases in strength compared to normal CVC at the age of 28 days concrete.

In 2016 carried out an innovative use of waste paper sludge in concrete as a supplementary cementitious material was tested as an alternative to normal concrete. The paper sludge ash was replaced with cement from 0% to 7.5% at an increment of 2.5%. Using M25 mix and tested for compressive, split tensile & flexural strength of concrete at 28 days the age of concrete compared with normal concrete. From the test results, it was observed that the use of 5% by weight of paper sludge replacement of cement leads to an early strength and improve the performance compared to conventional concrete.

Was conducted [5] an experimental study on cement concrete by partially replacing cement with paper sludge and natural sand with crushed sand simultaneously. The hypo sludge was replaced by cement 0%, 10%, 15% and 30%. M-sand was replaced by natural sand at 0% to 30% at an increment of 10%. Using M20, M25 and M30 mix with OPC the strength was determined at the age of 7, 14 and 28 days. From the result, it was observed that 1.44, 1.85 and 1.99 the percentage increase in strength with replacement of paper sludge for cement and also it was observed that 1.21, 1.99 and 1.95% increase in strength with replacement of sand by M-sand for M30 concrete.

In (2014) have investigated the structural performance of concrete by partial replacement of cement with hypo sludge. Two design mixes were chosen for hypo sludge to achieve M20 & M30 grades concrete using OPC with the percentage of replacement 0 to 30 % at an increment of 10% by weight of cement and water binder ratio is 0.55 and 0.45 respectively. From the test results, it was observed that the use of 20% by weight of hypo sludge substitute to cement increase the strength of concrete compare to CVC. He concluded that WPSA can be utilizing in concrete for general structures.

Sumit A et al have conducted on the cement has been replaced by paper sludge according to a range of 0 to 20 % at an increment of 5% by weight of cement for M-20 and M-30 design mix with adequate W/c ratio and compared to normal concrete. From the test results, it was carried out and observed that the use of 10% paper sludge increase the mechanical properties of concrete compares to CVC at the age of 28 days.

Gracia R et al have conducted the pozzolanic properties of paper sludge waste. In this research, it is observed that deinking paper sludge calcinations condition at 700^0 c and duration for 2 hours produce a highly reactive mineralogical composition of paper sludge. From the test result, it was observed that 10% replacement of calcined sludge with replacement of cement increase the compressive strength of cement mortar at 7 days age of concrete.

Vegas I et al [9] have investigated the calcined paper sludge use as a pozzolana supplementary cementing material. The deinking sludge was thermally activated in the range of 650^0 c to 700^0 c to study the mineralogical and chemical composition of sludge. Calcite and metakaolinite have an active influence on the mechanical and physical properties of the member. In the test results, it was observed that cement mortar containing 20% replacement of calcinated sludge increase the initial setting time and workability reduced and thermally activated sludge enhance the compressive strength at 7 days the age of curing.

Rameshwar S e al (2017) has conducted on the replacement of natural sand by crushed rock sand in the concrete. The sand was replaced by crushed sand varies from 0 to 100% at an increment of 10%. Compressive strength & split tensile strength were conducted using 53 grades OPC in M20and M25 concrete. From the test results, it was observed that 40% to 50% gives a maximum compressive strength is obtained and maximum tensile strength achieve a 60% to 70% replacement of natural sand with crushed sand. From the above test results, it was concluded that crushed sand was used as an effective replacement for natural sand.

Was conducted [11] analyzed through experimental study the use of M-sand as a replacement to natural sand from 0%, 20%, 40%, 60%, and 100%. The experiments were conducted using OPC 43 grade in M20 and M30 concrete. From the results, it was observed that workability decreased increase in the M-sand due to particle shape is angular and compensate use admixture. The 60% replacement of sand by crushed sand nearly 20% increase in good compressive, tensile and flexural strength and good durable property of 5% concentration of Hydrochloric acid resistance.

Another study was carried out by Naga Prashanth P et al study the alternative industrial material such as manufactured sand in the concrete mix. The research work is carried out to replace the M-sand with natural sand from 0 to 60% at an increment of 20%. It is observed that compressive, split tensile and flexural strength values are increased up to 60% substitute with crushed sand when compared to the natural sand aggregate concrete specimen.

In 2016 carried out on the use of crushed rock sand alternative to natural river sand used as fine aggregate in cement concrete. The properties of crushed rock sand are similar to the CVC. In the test result, it is observed that 50% replacement of CRS good compressive strength and reduction in strength beyond the replacement. For the 70 to 100 % replacement of crushed rock sand, it requires a proper washed CRS along with screening to achieve higher compressive strength.

Martins P et al use manufactured sand as a 100% replacement of natural sand to study the fresh and hardened properties of concrete. From the test result, it was observed that the compressive strength and flexural strength of M-sand were slightly higher than the natural sand concrete. The workability of crushed sand concrete is slightly lower than the natural sand concrete due to the presence of angular particles.

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Balamurugan G et al [24] carried out the behaviour of concrete on the use of quarry dust to replace sand in an experimental study. The sand was replaced by quarry dust varies from 0 to 100% in steps of 10% to study the compressive, split tensile and flexural strength using 43 grade OPC in M20 and M25 grade of concrete at 7 and 28 days age of concrete. From the test result, it was observed that 50% replacement of sand by quarry dust gives a higher strength compared to CVC. Table No: 4, Fig.2 and Fig.3 represent the summary of literature review percentage replaced of WPSA and CRS in concrete.

Table 4: Summary of the literature review based on cement replaced by paper sludge ash and sand by crushed rock sand.

Sl .No	References and Years	Partial Replacement of cement by WPSA and sand by crushed rock sand in concrete	Results
1	[1], 2013	WPSA 0%,10%,20%,30%, and 40%	10%
2	[2], 2015	WPSA 0%,10%, 15% & 20%	15%
3	[3], 2013	WPSA 0%,5%, 10%,15%, 20%	5%
4	[4], 2016	WPSA 0%, 2.5%, 5% & 7.5%	5%
5	[5], 2016	WPSA 0%, 10%, 15%, & 30%	15%
6	[6], 2014	WPSA 0%, 10%, 20%, & 30%	20%
7	[7], 2018	WPSA 0%,5%, 10%, 15% and 20%	10%
8	[8], 2007	WPSA 0%, 10%	10%
9	[9],2017	WPSA 0%, 10%, 20%	20%
10	[10], 2017	CRS 0 to 100% step in 10%	70%
11	[11], 2015	CRS 0%, 20%, 40%, 60% & 100%	60%
12	[12], 2017	CRS 0%, 20%, 40% and 60%	60%
13	[13], 2016	CRS 0 to 100% step in 10%	100%
14	[17], 2016	CRS 100%	100%
15	[24], 2013	CRS 0 to 100% in step of 10%	50%

***WPSA= Waste paper sludge ash *CRS= Crushed rock sand**

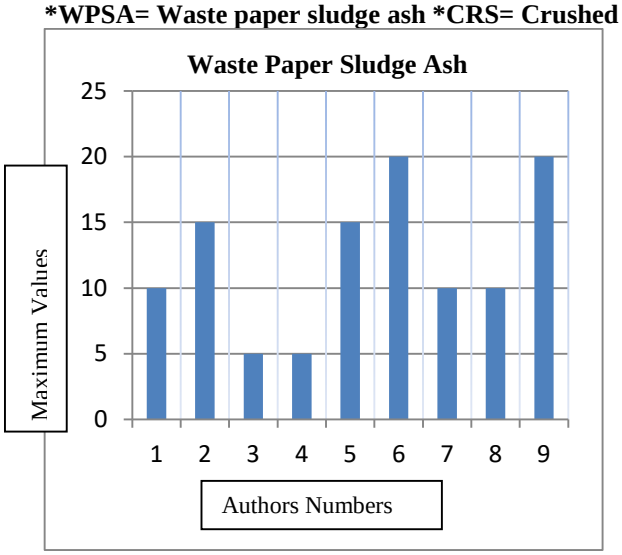

Fig.2 Waste Paper sludge ash used in concrete

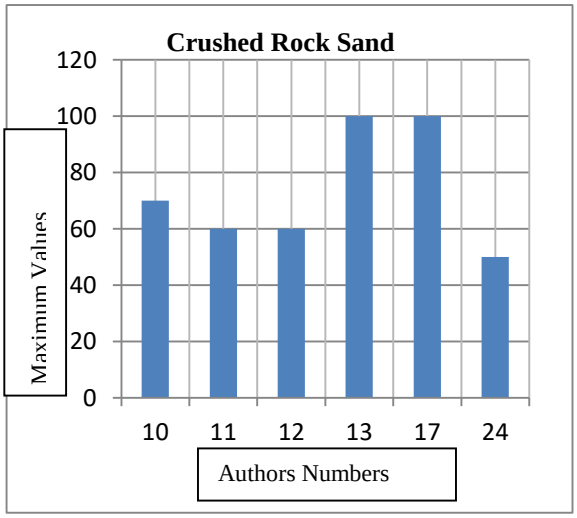

Fig.3 Crushed rock sand used in concrete

III ENVIRONMENTAL POLLUTION

Waste Paper sludge is a major and environmental problem for the paper industry. About 300 million tons of paper sludge is disposed of every year in India. The major problem is landfill, disposal, and environment hazards affected Sumit et al., [7] and Crushed rock sand is waste material is produced from the quarry, the aggregate crushing industry it is a large quantity nearly 200 million tons for every year it is a disposal and landfill and environment hazard [10]. The cement industry produces about 7% of carbon dioxide emission to the earth's atmosphere using the industrial by-product of waste paper sludge ash and crushed rock sand can minimize the scarcity of raw material and reduce the environmental hazards.

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IV CONCLUSION

From the above review it may be concluded that in general, Paper sludge and crushed rock sand as a raw material in the construction industry is reasonable without co-operating the material requirements according to available standards. Considering the huge cost, the complexity involved in the treatment and environmental factors, it can be demonstrated that the potential use of paper sludge and crushed rock sand in the construction industry is a substitute for the treatment, disposal of paper sludge and crushed rock sand and it would provide a solution to the waste problem. After referring to the research paper we can conclude that furthermore research should be done on the use of locally available waste or industrial by-products in concrete after investigating its final mechanical, physical properties and durability as well. The main aim of the research work is to produce economical and eco-friendly concrete with considering its desired properties.

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