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Mechanical Characteristics of Cement Mortar Manufactured with WPS Ash and PF as Partial Replacement for Cement and Sand

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ABSTRACT

The Waste discharged from paper mill is generally producing environmental issues, like, air and land pollution and land pollution. Therefore, it is planned to utilize the paper sludge in the form of ash after burning at high temperature in the incinerator for the replacement of cement and sand in cement mortar. In this research works, it is suggested to investigate mechanical characteristic of the cement mortar containing paper sludge. On the basis of the results obtained by conducting several tests, it is concluded that when the sand and cement replaced by the PS, the cube compressive strength, prism flexural strength and splitting tensile strength of cement mortar is gradually decreasing by increasing the percentage of waste paper sludge ash. It is also observed that, it is increasing when the cement mortar is incorporated with Polypropylene Fibre.

KEYWORDS: *Waste Paper Sludge, Super Plasticizer, Polypropylene Fibre, Cube compressive strength, Prism Flexural Strength, Splitting Tensile Strength*

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1. INTRODUCTION

Now – a – days concrete is the important building material. The concrete production is about 12 billion tons a year [1]. It is almost nearly $1m^3$ per person per day and correspondingly the production of cement is 3 billion tons per year [1]. The Paper industries recycles large amount of waste Paper Sludge (WPS) in the production of paper process and making new paper using the recycled waste. The WPS discharges on the land after recycled in the industries. The WPS disposed over the land is producing unhealthy environment, causing air pollution and land pollution. Sometimes the WPS has logged the pores of soil media in the underground and thus reducing the percolation of water in to ground through the pores. Therefore it is necessary to dispose the WPS in proper manner.

The recycling process of paper produces ash which has potential useful application in construction. The WPS contains cementitious properties. Hence the waste paper sludge ash is used as a construction material [2-4]. While comparing with PC, the WPS ash shows different hydration and setting behavior [5]. The WPS ash contains considerable amount of alumino-siliceous materials, majority of which appear to be combined with calcium [6]. The cement industries are doing research works with new sustainable development policies by using the by-products such as Fly ash, Silica fume , Blast furnace slag, rice husk and quarry dust etc. as active additions in the manufacturing of blended cement. Furthermost, the utilization of by-products provides the benefits of scientific, technical and economic nature such as improvement in the mechanical performance and durability of cement [7]. In this context, it is proposed to obtain active additions from the industrial by-products [8] other than those traditionally used in the cement industries. Addition of wastepaper sludge to geopolymer mortar reduces flow properties, primarily due to dry sludge absorbing water from the binder mix. The average 91-day compressive strength of mortar samples incorporating 2.5 wt% and 10 wt% wastepaper sludge respectively retained 92% and 52% of the reference mortar strength [9].

The brick with 5–20% addition of cement to Recycle Paper Mills Waste exhibits a compressive strength of 9 MPa which is three times greater than the conventional clay bricks (3 Mpa) and satisfies the requirements in BS6073 for a building material to be used in the indoor structural applications [10]. WPS is a cementitious material in which some constituents hydrate faster than others. The free lime in the WSA reacts with water immediately upon soaking and provides a highly alkaline pore solution, which then results in the release of more reactive phases such as Al_2O_3 and SiO_2 into the system[11].

Therefore, it is suggested to reuse the WPS in the form of ash for replacement of Sand and Cement in the Cement Mortar. The type of Paper Sludge is NG Kraft. This research works aims to investigate the mechanical properties such as Cube Compressive Strength, Prism Flexural Strength and Splitting Tensile Strength of Cement Mortar Containing Paper Sludge with and without incorporated Polypropylene Fibre.

2. MATERIALS USED IN THE RESEARCH WORK

The basic materials used in the present research work are: Ordinary Portland Cement (OPC) Grade 33, Fine Aggregate, WPS ash, Polypropylene Fibre, Super plasticizer and tap water.

2.1. Cement

The purpose of using the cement is to obtain strength and provide cohesion with other constituent materials which is used in the Cement Mortar. The cement used in the research work is OPC 33grade. The Specific Gravity of Cement used is 3.10. The cement contains large amount of Oxides of Calcium, Silicon, Aluminium and Iron.

2.2. Fine Aggregate

Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. The river bed sand is used in this research work. The size of the river sand is varying from 0.1mm to 2mm. The specific gravity and Fineness modulus of sand are 2.644 and 2.823 respectively.

2.3. Waste Paper Sludge (WPS)

WPS becomes a new innovation material that can be used as material for masonry to support the green technology due to less presence of Potassium at only 0.87% of the total weight. Oxides of Sodium and Sulphur emission also can be reduced since less cement productivity is involved. The chemical and physical properties of the WPS were determined by comparing it with the Ordinary Portland Cement (OPC). The chemical compositions of the WPS ash are mentioned in the table 1. It contains large amount of Oxides of Calcium (CaO), Silicon (SiO_2) and Aluminium (Al_2O_3). The WPS ash is used as a binder material for the replacement of Cement and Sand in the form of ash after burning the Sludge at 300°C in the incubator. The purpose of using the waste paper sludge in this research work is to reduce the self weight of member and avoid the air pollution as well as land pollution. The specific gravity of WPS is 3.163 and density is 636.62 kg/m^3.

2.4. Polypropylene Fibre

The total demand for polypropylene fibres in North America was 3,750 million pounds in 1998. The demand for PF is projected to grow at the rate of 5.2% annually for the next five years. The total demand for PF in Western Europe was about 3,520 million pounds in 1998, and it is projected to grow at 3% annually for the next five years.

The size of the PF used in the research work is 12mm length and orientation of the fibre is random. The product name of the fibre used is Recron 3S. The dosage of fibre is 0.5% by weight of Cement.

2.5. Superplasticizer

In this investigation, super plasticizer Conplast SP 430, based on sulphonated naphthalene polymers, complies with IS 9103- 1999, BS: 5075 part 3 and ASTM C – 494, Type F was used. Commercially available high performance superplasticizing admixture, Conplast SP430, conforming to ASTM C 494 (1992) was used to maintain the slump of the concrete. The properties, supplied by the manufacturer, are given in Table 1.

Table 1: Properties of superplasticizer

Properties	Conplast SP430
Composition	Sulphonated naphthalene formaldehyde condensate
Active solids (% by wt.)	40
Appearance	Brown liquid
Specific gravity	1.20 at 20°C
Air entrainment (%)	< 2
Chloride content (%)	Nil
pH value	7.0 - 8.0

3. PROPERTIES OF CEMENT MORTAR CONTAINING WPS

The Cement paste blended with 0%, 2%, 4%, 6%, 8%, 10% &, 15%, 20% and 25% were prepared to examine their mechanical properties, such as the Cube compressive strength at the age of 7 days and 28 days, Prism Flexural strength at the age of 28 days and splitting tensile strength of cylinder at the age of 28 days of Cement Mortar containing WPS for the replacement of Sand as well as Cement were casted and tested. The tests were conducted in the Universal Testing Machine Electronic 60 Tonne Capacity to obtain the Compressive Strength of the Cubes, Flexural Strength of Prism and Splitting Tensile Strength of Cylinder.

The mix design for all the mortars is indicated in the table 2. The Cement (binder): Sand ratio kept as 1:3 and Water: Cement (binder) ratio was 1:2 for all mortars. The Superplasticizer Conplast SP 430 is used to improve the flow property at the rate of 1 litre per m^3 of CM.

Table 2: Mix Design of Cement Mortar samples containing WPS

Sl. No	% of WPS Ash	For replacement of Sand				For replacement of Cement			
		Wt. of Cement in g	Wt. of sand in g	Vol. of water in ml	Wt. of WPS Ash in g	Wt. of Cement in g	Wt. of sand in g	Vol. of water in ml	Wt. of WPS Ash in g
1	0	450	1350	225	0	450	1350	225	0
2	2	450	1323	225	27	441	1350	225	9
3	4	450	1296	225	54	432	1350	225	18
4	6	450	1269	225	81	423	1350	225	27
5	8	450	1242	225	108	414	1350	225	36
6	10	450	1215	225	135	405	1350	225	45
7	15	450	1147	225	203	383	1350	225	68
8	20	450	1080	225	270	360	1350	225	90
9	25	450	1012	225	338	338	1350	225	113

4. RESULTS AND DISCUSSIONS

4.1. Cube Compressive Strength

3 Nos. of 70.7 x 70.7 x 70.7 mm cubes were casted and tested at the age of 7 days and 28 days curing for each replacement of Paper Sludge for Sand and Cement. The percentage of replacement of Paper Sludge is 0%, 2%, 4%, 6%, 8%, 10% &, 15%, 20% and 25%.

The Figure 1 and 2 shows the Compressive Strength of the Cement Mortar cubes at the age of 7 days and 28 days respectively for the replacement of Sand and Cement with and without adding Polypropylene Fibre.

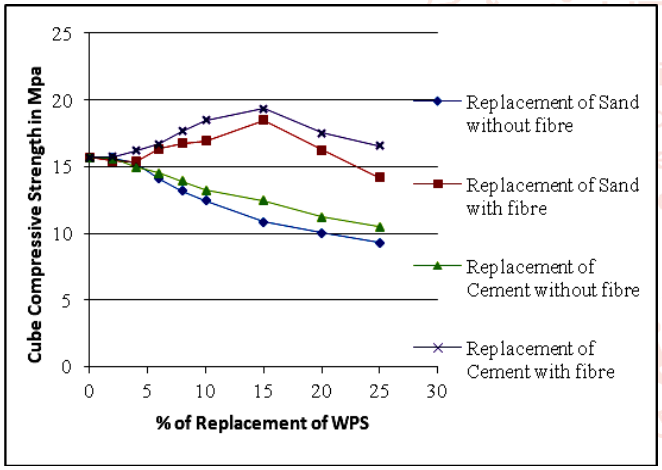

Fig.1: Cube Compressive Strength in Mpa at the age of 7 days containing WPS

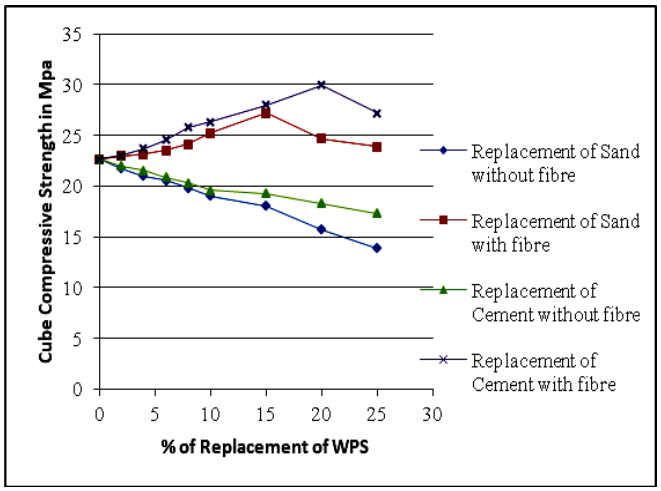

Fig.2: Cube Compressive Strength in Mpa at the age of 28 days containing WPS

The results shows that the Compressive Strength of Cement Mortar cubes is gradually decreasing for each percentage of replacement of Paper Sludge for Sand and Cement without adding Polypropylene Fibre at the age of 7 days and 28 days.

Compressive Strength of cube which is maximum at the rate of 15% of replacement for Sand with Polypropylene Fibre is 18.48 Mpa at the age of 7days curing and 27.21 Mpa at the age of 28 days curing for the same replacement, where as the compressive Strength is maximum at the rate of 15% of replacement for Cement is 19.37 Mpa and 27.16 Mpa at the age of 28 days curing for 20% of the replacement of Cement.

4.2. Prism Flexural Strength

3 Nos. of 50 mm x 50mm x 150mm Prism were casted and tested at the age of 28 days curing for each replacement of Paper Sludge for Sand and Cement. The percentage of replacement of Paper Sludge is same as in the case of cube compressive strength.

The Figure 3 shows the Flexural Strength of the Cement Mortar Prism at the age of 28 days for the replacement of Sand and Cement with and without adding Polypropylene Fibre. The results shows that the Flexural Strength of Cement Mortar Prism is gradually decreasing for each percentage of replacement of Paper Sludge for Sand and Cement without adding Polypropylene Fibre at the age of 28 days.

Flexural Strength of Prism which is maximum at the rate of 15% of replacement for Sand with Polypropylene Fibre is 4.55 Mpa at the age of 28 days curing, where as it is maximum at the rate of 20% of replacement for Cement which is 6.37 Mpa.

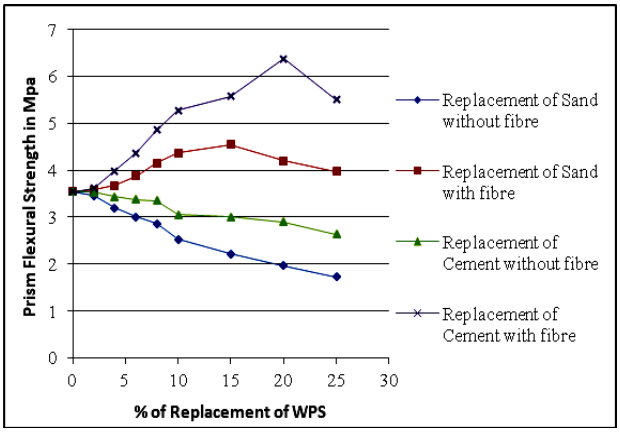

Fig.3: Prism Flexural Strength in Mpa at the age of 28 days containing WPS

4.3. Splitting Tensile Strength of Cylinder

3 Nos. of 50 mm diameter and 100mm length cylinders were casted and tested at the age of 28 days curing for each replacement of Paper Sludge for Sand and Cement. The percentage of replacement of Paper Sludge is same as in the case of cube compressive strength.

The Figure 4 shows the Splitting Tensile Strength of the Cement Mortar cylinder at the age of 28 days for the replacement of Sand and Cement with and without adding Polypropylene Fibre. The results shows that the Splitting Tensile Strength of Cement Mortar cylinder is gradually decreasing for each percentage of replacement of Paper Sludge for Sand and Cement without adding Polypropylene Fibre at the age of 28 days.

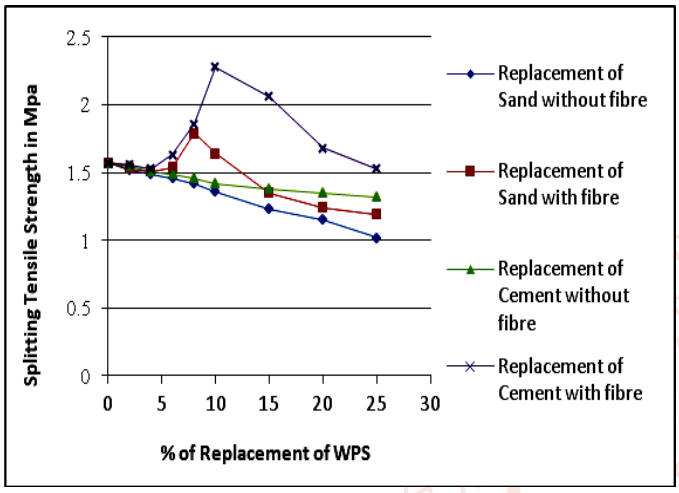

Fig.4: Splitting Tensile Strength of Cylinder at the age of 28 days containing WPS

Splitting Tensile Strength of Cylinder which is maximum at the rate of 8% of replacement for Sand with Polypropylene Fibre is 1.79 Mpa at the age of 28 days curing, where as it is maximum at the rate of 10% of replacement for Cement which is 2.28 Mpa.

5. CONCLUSIONS

- The Compressive Strength of the Cube, Flexural Strength of the Prism and the Cylinder Splitting Tensile Strength of the Cement Mortar containing the WPS ash is gradually reducing while increasing the percentage of the replacement of the Paper Sludge without adding Polypropylene Fibre for both the replacement.
- Compressive Strength of cube is maximum at the rate of 15% of replacement for Sand with Polypropylene Fibre is 18.48 Mpa (more than 17.93% than the Control Specimen) at the age of 7days curing and 27.21 Mpa (more than 20% than the Control Specimen) at the age of 28 days curing for the same replacement, where as the compressive Strength is maximum at the rate of 15% of replacement for Cement which is 19.37 Mpa (more than 23.61% than the Control Specimen) and 27.16 Mpa (more than 32.06% than the Control Specimen) at the age of 28 days curing for 20% of the replacement.
- Flexural Strength of Prism is maximum at the rate of 15% of replacement for Sand with Polypropylene Fibre is 4.55 Mpa (more than 28.53% than the Control Specimen) at the age of 28 days curing, where as it is maximum at the rate of 20% of replacement for Cement which is 6.37 Mpa. (more than 79.09% than the Control Specimen)
- Splitting Tensile Strength of Cylinder is maximum at the rate of 8% of replacement for Sand with Polypropylene Fibre is 1.79 Mpa (more than 14.01% than the Control Specimen) at the age of 28 days curing, where as it is maximum at the rate of 10% of replacement for Cement which is 2.28 Mpa. (more than 45.22% than the Control Specimen)

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