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Study of Structural Performance and Durability of Concrete by Partial Replacement of Cement with Hypo Sludge (Paper waste)

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Abstract: Utilization of industrial waste products as supplementary cementitious materials (SCM) in concrete making is very important aspect in view of economical, environmental and technical reasons. As these supplementary cementitious materials have different chemical and mineralogical composition, their effect on micro structural properties and strength performance vary considerably. While producing paper, various wastes come out from the various processes in paper industries. The preliminary waste from paper industry is named as hypo sludge. In this study the material obtained from the paper industry waste (hypo sludge) is admixed with Portland cement at different replacement levels. The properties of concrete investigated include compressive strength, split tensile strength, flexural strength, sorptivity and acid effect keeping optimum percentage of hypo sludge supposedly supplementary cementitious material (SCM). In this work, M20 grade was developed using IS method of mix design. Specimens of dimensions of 150 x 300mm cylinders for split tensile strength and dimensions of 100 x 100 x 500mm prisms for flexure strength and 150*150*150mm cubes were cast, with and without hypo sludge and tested under axial compression to justify the compressive strength for 7 and 28 days. Standard cubes were immersed in 5%HCL, 5%H_2SO_4 for inspecting the durability properties. The Sorptivity test has also been conducted. It is concluded that hypo sludge concrete had better mechanical properties and durability properties compared to normal concrete. Test results indicate that the use of hypo sludge in concrete has improved the performance of concrete from strength as well as durability aspects. The split tensile strength is less in hypo sludge concrete compared to normal concrete.

Key words : Hypo Sludge,Concrete,M_{20} grade concrete, cubes, cylinders, prisms, durability.

I. INTRODUCTION

The environmental aspects involved in the production of and use of cement, concrete and other building materials are of growing importance. Producing one ton of cement results in the emission of approximately one ton of CO_2. SO_2 emissions is also very high, but is dependent upon the type of fuel used .Energy consumption is also very high at 90-150 KWT/ton of cement produced. It is costly to erect new cement plants. Substitution of waste materials will conserve resources, and will avoid environmental and ecological damages caused by quarrying and exploitation of the raw materials for making cement. While the developed, industrialized countries are called upon to reduce pollution of the environment and their share of the usage of the world's resources, including energy, the developing countries need to avoid the mistakes of the past. This problem is particularly acute, since cement production as well as fly ash generation in China and India are expected to increase significantly in the next few decades. There is an increasing demand for concrete worldwide, estimated to double within the next 30 years. This demand can be met without a corresponding increase in greenhouse gases by using supplementary cementitious materials to replace a maximum amount of the cement in concrete, we can reduce energy and resource consumption, reduce CO_2 emissions, and reduce the negative environmental impact. There is a further environmental benefit in that most commonly used supplementary cementitious materials (such as hypo sludge, fly ash, silica fume) are waste products and would otherwise end up in landfills. Paper making generally produces a large amount of solid waste. It means that the broken, low-quality paper fibers are separated out to become waste sludge. This paper mill sludge consumes a large percentage of local landfill space every year and also contributes to serious air pollution problems. To reduce disposal and pollution problems emanating from these industrial wastes, it is most essential to develop profitable building materials from them. This report concisely explains the technical and environmental benefits of supplementary cementitious materials use, as well as the limitations, applications and specifications.

Benefits of Hypo Sludge

- Hypo sludge improves the properties of fresh and harden concrete.
- Hypo sludge reduces degradation and bleeding.
- Hypo sludge improves the durability of concrete.
- Hypo sludge improves the setting of concrete due to presence of silica and magnesium.
- Environmental friendly.
- Light weight compare to conventional concrete.
- Hypo sludge is the cheaper substitute to OPC.

Limitations of Hypo Sludge

- Availability
- Handling problem

II. MATERIALS AND PROPERTIES

The materials used in research are:

1. Portland cement (53 grade)
2. Fine aggregate (4.75 mm down)
3. Coarse aggregate (20 mm down)
4. Hypo Sludge

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5. Water
6. Admixtures

Cement:

Ordinary Portland cement of 53 grade conforming to Indian Standard IS 12269-1987 was used throughout the experimental program. Cement must develop the appropriate strength. It must represent the appropriate rheological behavior. Generally same types of cements have quite different rheological and strength characteristics, particularly when used in combination with admixtures and cementing material.

Fine Aggregate

Fine aggregate (sand) used for this entire investigation for concrete was river sand conforming to zone-II of IS: 383-1970. Fine aggregate normally consists of natural, crushed, or manufactured sand. The physical properties of fine aggregate like specific gravity, gradation and fineness modulus are tested in accordance with IS :2386.

Coarse Aggregate

Coarse aggregate crushed granite of 20 mm down size has been used as coarse aggregate. The physical properties of coarse aggregate like specific gravity, Bulk density, impact value, gradation and fineness modulus are tested in accordance with IS: 2386.

Hypo Sludge

The preliminary waste from paper industry is named as hypo sludge. The hypo sludge contains, low calcium, maximum calcium chloride and minimum amount of silica. Hypo sludge behaves like cement because of silica and magnesium properties. This silica improves the setting of the concrete.

The sludge which used in present investigation is brought from Vamsadhara paper mills Ltd. at madapam.

Table 1: Chemical Properties of Hypo Sludge

Sl.No.	Constituent	Percent in Hypo sludge(%)
1	Moisture	56.8
2	Magnesium Oxide (Mgo)	3.3
3	Calcium Oxide (CaO)	46.2
4	Silica (SiO_2)	9.0
5	Acid Insoluble	11.1

Water

The water, which is used for making concrete and for curing, should be clean and free from harmful impurities such as oil, alkali, acid, etc, in general, the water, which is fit for drinking should be used for making concrete.

III. MIX DESIGN

A mix M_{20} grade was designed as per IS 10262:2009 and the same was used to prepare the test samples. The design mix proportion is shown in blow table.

Table 2: Concrete Mix Design Proportion for 1 m^3 of concrete

Sl. no.	Hypo sludge %	w/c ratio	Cement	Fine Aggregate	Coarse Aggregate	Hypo Sludge
1	-	0.5	1.0	1.96	2.85	-
2	10	0.5	0.9	1.96	2.85	0.10
3	20	0.5	0.8	1.96	2.85	0.20
4	30	0.5	0.7	1.96	2.85	0.30

IV. EXPERIMENTAL PROGRAMME

The quantity of cement, fine and coarse aggregates, hypo sludge and water each batch of proportion is prepared as mentioned in mix design. Then the mixing process is carried out.

Test for Fresh concrete

Workability tests included the determination of slump cone test.

Tests for Hardened properties of hypo sludge concrete

To determine the hardened properties of concrete standard tests were carried out at standard ages (7days and 28 days of curing) i.e., compression test on cubes for compressive strength (72 cubes of 150x150x150mm size), split tensile test on cylinders for tensile strength (12 cylinders of 150mm dia with 300mm height) and flexural test on beams for flexural strength (12 prisms 150x500mm) of concrete for each grade with different mix proportions of hypo sludge.

V.RESULTS AND DISCUSSION

Slump Cone Test results

Slump cone test conducted on fresh concrete and the results are shown in table

Table 3:Results of Slump Cone Test M_{20}

Mix Designation	M_{20} Slump cone (mm)
-	53
10%	50
20%	47
30%	43

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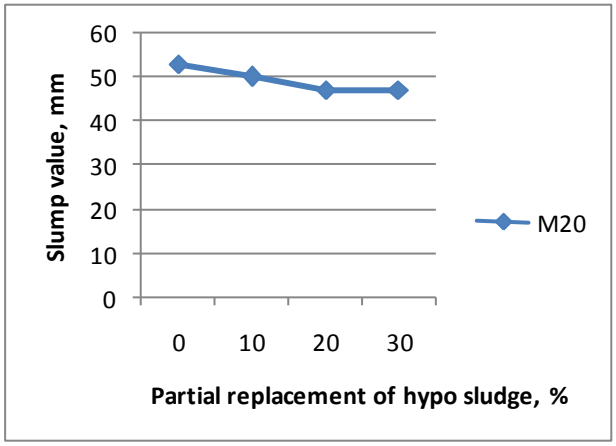

Table 4: Mechanical Properties of Concrete with Different mix Proportions

Partial replacement of hypo sludge in %	compressive Strength (N/mm²)		Split tensile Strength (N/mm²)	Flexural Strength (N/mm²)
	7 days	28 days	28 days	28 days
0	17.42	27.66	0.416	1.510
10	21.55	32.05	0.297	1.570
20	23.79	35.24	0.273	1.610
30	24.90	36.98	0.260	1.720
40	20.06	25.90	-	-
50	17.13	22.75	-	-

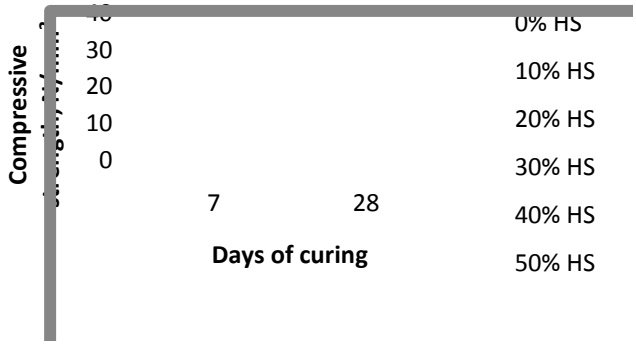

Fig 1: compressive strength vs age for 7 and 28 days

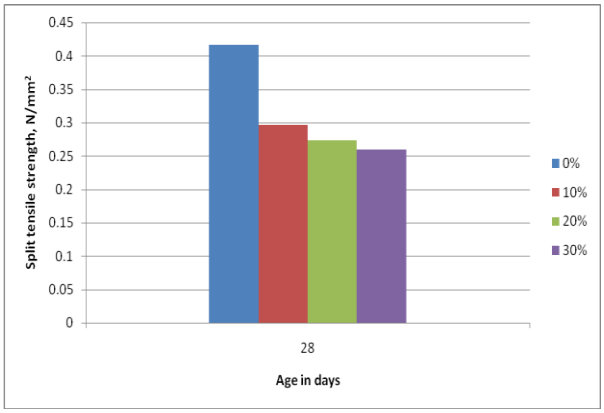

Fig 2: Comparison specimens for split tensile strength

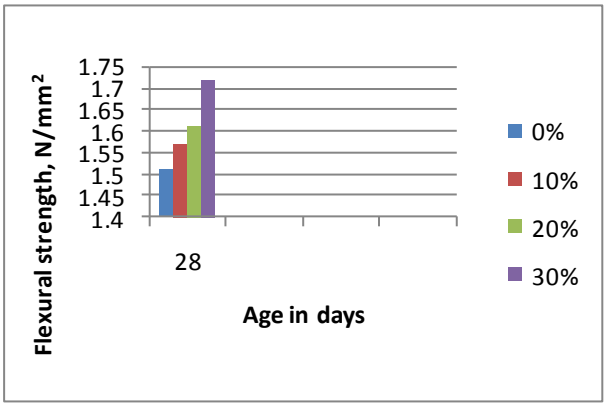

Figure 3: Flexural strength for 28 Days

Table 5: Percentage mass losses when immersed in5% of H_2SO_4 & HCL

Partial replacement of hypo sludge in %	% of mass loss when immersed in 5% of H_2SO_4			% of mass loss when immersed in 5% of HCL		
	3 Days	7 Days	28 Days	3 Days	7 Days	28 Days
0	-2.247	-0.67	4.49	0.56	1.34	3.337
10	-0.568	-0.23	1.70	0.35	1.73	3.11
20	-1.626	0.12	1.74	0.58	1.76	3.52
30	-1.193	0.82	2.11	0.59	0.94	1.1

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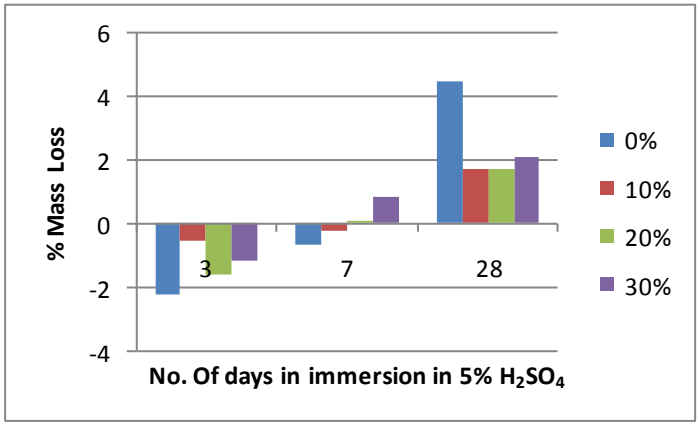

Figure 4: Percentage mass loss when immersed in 5%Sulphuric acid solution

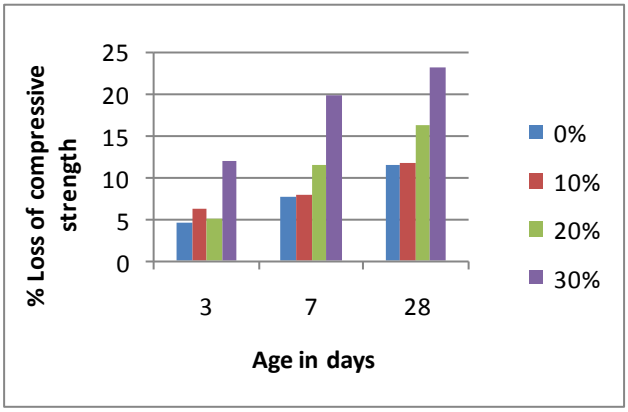

Figure 6: % loss of Compressive Strength for cubes immersed in 5% H_2SO_4

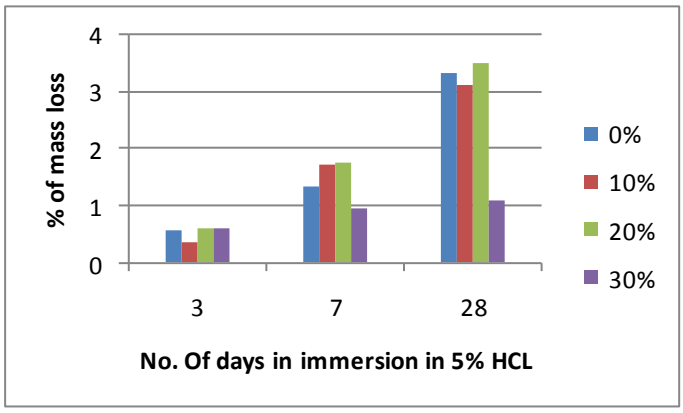

Figure 5: Percentage mass loss when immersed in 5% of HCL

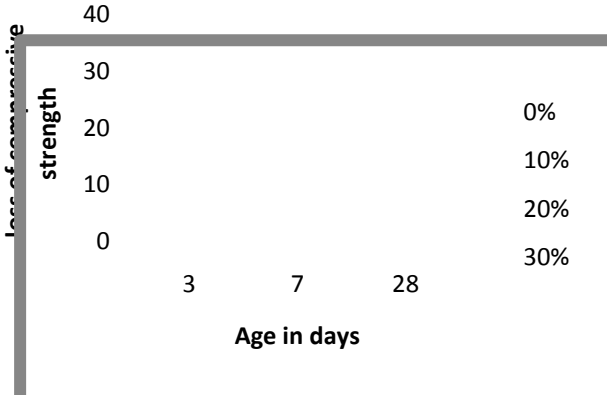

Figure 7: % loss of Compressive Strength for cubes immersed in 5% Hcl

Table 6: % losses of compressive strength for 5% of H_2SO_4 & HCL

Partial replacement of hypo sludge in %	% loss of compressive strength for 5% of H_2SO_4			% loss of compressive strength for 5% of HCL		
	3 Days	7 Days	28 Days	3 Days	7 Days	28 Days
0	4.55	7.80	11.64	4.19	7.44	10.05
10	6.20	7.95	11.8	8.26	17.16	24.32
20	4.93	11.46	16.28	19.4	24.63	33.78
30	11.90	20.05	23.33	9.21	17.61	24.67

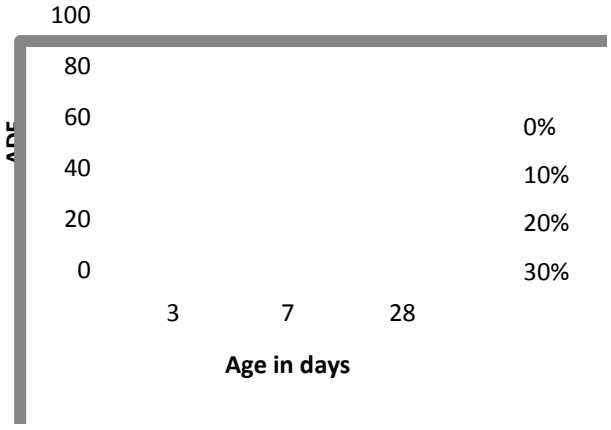

Fig 8: Graph between Acid Durability Factor and No. of days in immersion in 5% H_2SO_4

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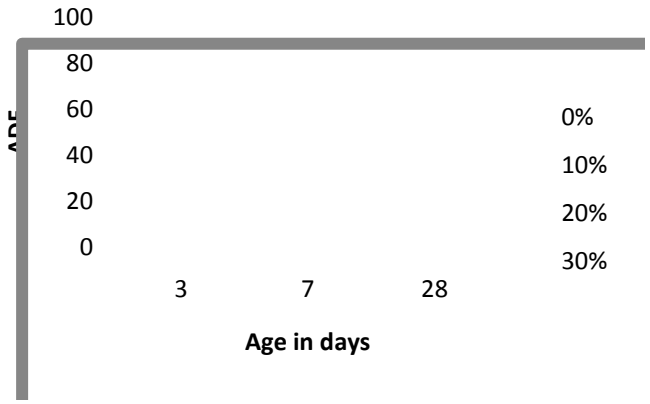

Fig 9: Graph between Acid Durability Factor and No. of days in immersion in 5% Hcl

By this table and graphs shows that there is an increase in compressive strength, flexural strength with 10%,20%,30% replacement of cement with hypo sludge and it decreases with 40% replacement and the percentage mass loss for hypo sludge with 10% replacement is less in 5% H_2SO_4 and 5% HCL when compared to other replacements.

VI. CONCLUSION

The present work deals with effect of hypo sludge on strength and durability properties of normal concrete. The conclusions obtained from the study are

1. The replacement of cement with hypo sludge is done from 0% to 50%. The maximum compressive strength for 28 days is achieved for 30% replacement of cement by hypo sludge. The percentage increase in compressive strength for 30% replacement to normal concrete is 33.69.
2. The flexural strength is increased from 0% to 30% replacement and the percentage increase for 30% to normal concrete is 13.09.
3. After 28 days the percentage mass loss for hypo sludge with 10% replacement is 1.705%in 5% sulphuric acid (H_2SO_4) which is less when compared to other replacements.
4. After 28 days the percentage mass loss for hypo sludge with 10% replacement is 1.1% in 5% Hydrochloric acid (Hcl) which is less when compared to other replacements.
5. After 28 days the percentage loss of compressive strength for the cubes immersed in 5% H_2SO_4 and 5% Hcl are less for normal concrete when compared to hypo sludge concretes.
6. The Acid Durability Factor (ADF) for normal concrete are more for cubes kept in 5% H_2SO_4 and 5% Hcl and the corresponding values are 88.36 and 89.95. Hence normal concrete is durable.
7. The coefficient of sorptivity for 30% hypo sludge concrete is less compared to all other concretes (0%, 10%, 20%).

8. Hence, it can be concluded that hypo sludge concrete is good enough to satisfy the requirements for compressive strength, flexural strength and sorptivity. But it has failed in satisfying durability requirements.

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