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To Evaluate the Properties of Concrete Prepared Using Waste Paper Sludge

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ABSTRACT - This study explores the potential of using waste paper sludge, a by-product of the paper industry, as a partial replacement for cement in M25 grade concrete. Concrete mixes were prepared with varying percentages of paper sludge: 0%, 10%, 20%, 30%, and 40%. The objective was to evaluate the effect of this substitution on the workability, compressive strength, and flexural strength of the concrete, as well as to identify the optimum replacement level. Results revealed that concrete incorporating up to 30% paper sludge exhibited enhanced strength and durability compared to conventional concrete. The mix with 30% replacement showed the highest compressive strength, while the 40% mix achieved strength nearly equal to the control mix. Additionally, an increase in curing time improved both strength and sulphate resistance across all mixes. The findings indicate that paper sludge can be effectively utilized as a sustainable cement replacement material, with 30% being the optimal level for structural performance and environmental benefit.

Keywords: Waste paper Sludge, M25 grade of concrete, flexural strength, split tensile strength

I. INTRODUCTION

The cement industry is a major contributor to global carbon dioxide (CO_2) emissions, accounting for around 7% of total greenhouse gas emissions. This is largely due to the calcination of limestone during clinker production, an energy-intensive process that also relies heavily on fossil fuels. Moreover, the industry consumes vast quantities of natural resources such as limestone, clay, and sand, leading to environmental degradation and resource depletion.

To address these challenges, sustainable alternatives are being explored to reduce the industry's carbon footprint. One key strategy involves replacing or supplementing traditional cement with alternative binders made from industrial by-products and waste materials. Common examples include fly ash, slag, and natural pozzolans, which possess pozzolanic properties that enhance concrete durability and reduce clinker demand. An emerging alternative is waste paper sludge, a by-product of the paper recycling industry. When treated appropriately, it can contribute to cementitious behavior while reducing landfill waste and lowering CO_2 emissions.

Additionally, innovations such as carbon capture and utilization (CCU) are being developed to further mitigate emissions by repurposing captured CO_2 for use in concrete or building materials. While promising, CCU technologies are still under research and face economic barriers.

In conclusion, transitioning toward sustainable cement production involves incorporating alternative binders like fly ash, slag, natural pozzolans, waste paper sludge, and geopolymers, along with advancing carbon capture methods. These efforts can reduce environmental impact and promote responsible construction practices, aligning the industry with global sustainability goals.

II. MATERIAL AND METHODOLOGY

The investigation focuses on assessing the properties of various materials used in concrete production and their impact on the final product. The materials, including cement, sand, coarse aggregates, fine aggregates, and waste paper sludge, are meticulously sourced and characterized based on relevant physical properties. This ensures a comprehensive understanding of their behavior within the concrete mix. Laboratory testing plays a pivotal role in scrutinizing the properties of these materials.

The study aims to develop a mix design for M25 grade concrete. This involves conducting tests on the materials to ascertain their suitability and performance in the desired concrete grade. The primary objectives of the study are clearly outlined:

1. To develop concrete mix of M25 grade of concrete by using 0,10,20,30 and 40 % age of waste paper sludge.

2. To find the optimum %age of waste paper sludge in developing concrete mix.

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3. Evaluation of the workability, compressive strength and flexural strength test of the concrete mixes.

By systematically analyzing the workability, compressive strength and flexural strength of the concrete mixes under different conditions, the study aims to provide insights into the feasibility and efficacy of incorporating waste paper sludge in M25 grade concrete production. This research endeavor holds promise for enhancing sustainability in construction practices by utilizing recycled materials without compromising performance.

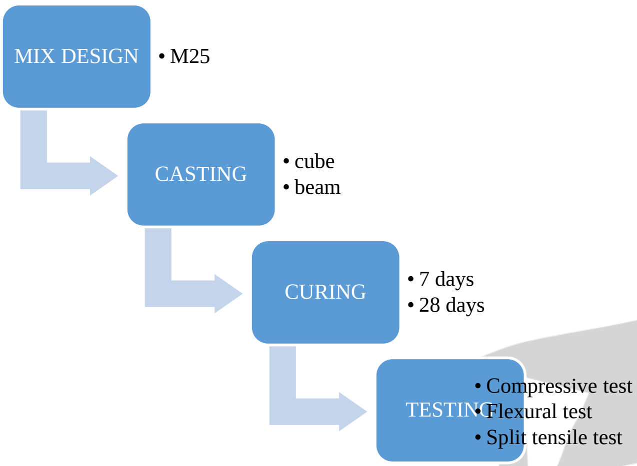

Figure 1: Hierarchy of Work

III. MATERIAL USED

The material used for this investigation is cement, coarse and fine aggregate, appropriate water, Admixture and waste sludge in appropriate %age.

a) CEMENT

Cement is the core material in concrete which acts as a binding agent and imparts strength to the concrete. The cement used for this study Ordinary Portland cement of Grade 43 Ultra Tech. The physical properties of used cement as below in

Table 1: Physical Properties of Cement

Sr.No.	Characteristics	Experimental value	Specified value as per IS:8112-1989
1.	Consistency of cement (%)	32%	30-35%
2.	Specific Gravity	3.05	3.15
3.	Initial setting time (min)	31	>30 As Per IS4031-1968
4.	Final setting time (min)	450	<600 As Per IS4031-1968
5.	Compressive strength (N/mm^2)		
	i) 3 days	27.56	>23
	ii) 7 days	40.57	>33
	iii) 28 days	48.96	>43
6.	Soundness (mm)	2.3	10
7.	Fineness of Cement	6%	10% As Per IS269-1976.

b) WATER

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. The water, which is used for making concrete should be clean and free from harmful impurities like oil, alkalis, acids etc. Water for making concrete should have pH between 6 and 8. Locally available drinking water was used in this work is covering requirements as per IS-456:2000.

Result: pH 5

c) AGGREGATE

It is defined as: "Aggregates are the inert materials that are mixed in fixed proportions with a Binding Material to produce concrete". These act as fillers or volume increasing components on the one hand and are responsible for the strength, hardness, and durability of the concrete on the other hand.

i) Fine Aggregate

Table 2: Various Parameter of Fine Aggregate

Sr no	Particulars	Values
1.	Specific gravity	2.63
2.	Bulk Density	1.21 x 103 Kg/m3
3.	% of voids	54%
4.	Water absorption	1%
5.	Moisture content	1.4%

ii) Coarse Aggregate

Table 3: Various Parameter of Coarse Aggregate

Sr no	Particulars	Values
1.	Specific gravity	2.81
2.	Bulk Density	1.42 x 103 Kg/m3
3.	% of voids	50%
4.	Water absorption	0.5%
5.	Deval's abrasion	8.6%

d) WASTE PAPER SLUDGE

Waste Paper Sludge (WPS) is a by-product produced during the recycling and manufacturing of paper. It is generated mainly during the de-inking, screening, and washing stages, where unwanted materials are separated from reusable paper fibers. WPS primarily

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contains pulp fibers, ash, clay, calcium carbonate, and cellulose, along with trace amounts of heavy metals and chemical additives used in paper processing. The properties of WPS tested are:

Table 4: Properties of WPS

Sr No	Particulars	%
1	Lime	49
2	Silica	5.5
3	Alumina	2
4	Magnesium	1.4
5	Sodium Oxide	1.6

IV. RESULT AND DISCUSSION

a) WORKABILITY

The workability of the mix prepared is described in table 5.1.

Table 5: Slump Value

Mix designation	%age of WPS	Slump Value in mm
S1	0	100
S2	10	85
S3	20	89
S4	30	70
S5	40	78

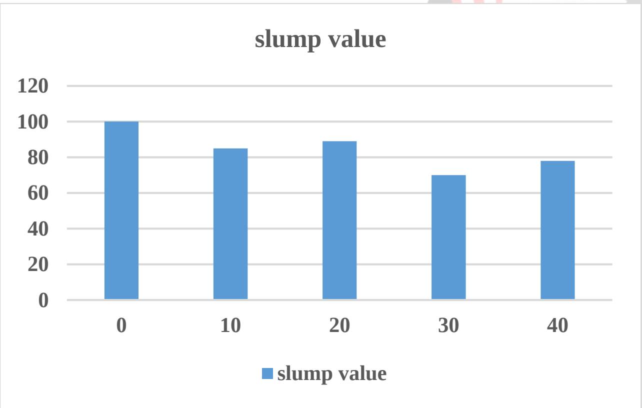

Figure 2: Variation of Slump Value

b) COMPRESSIVE STRENGTH

Test specimens of size 150 *150* 150 mm were prepared for testing the compressive strength concrete. The concrete mixes were cast into cubes, Beam and cylinders for subsequent testing.

Table 6: Compressive strength of concrete

Sr No.	Partial Replacement in %age	Ultimate compressive strength (kN)	
		7 days	28 days
1	0	16.80	28.12
2	10	18.30	30.33
3	20	19.77	31.19
4	30	19.555	28.12
5	40	17.95	36.33

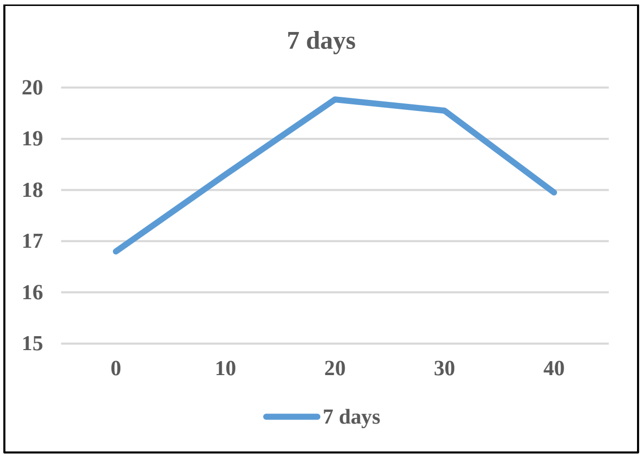

Fig 3: Compressive strength after 7 days

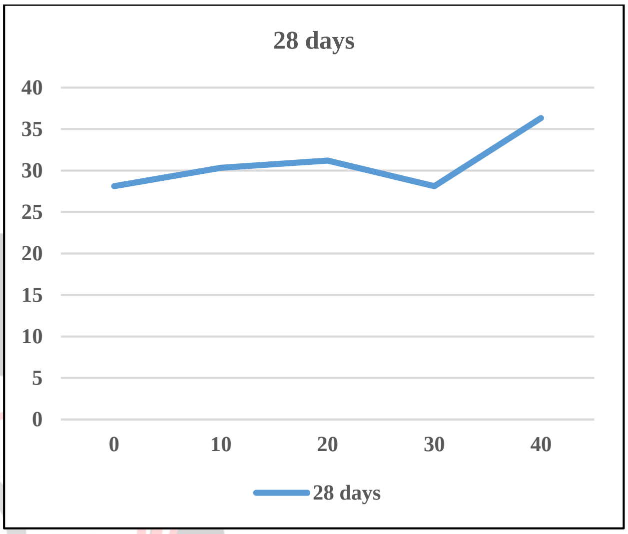

Fig 4: Compressive strength after 28 days

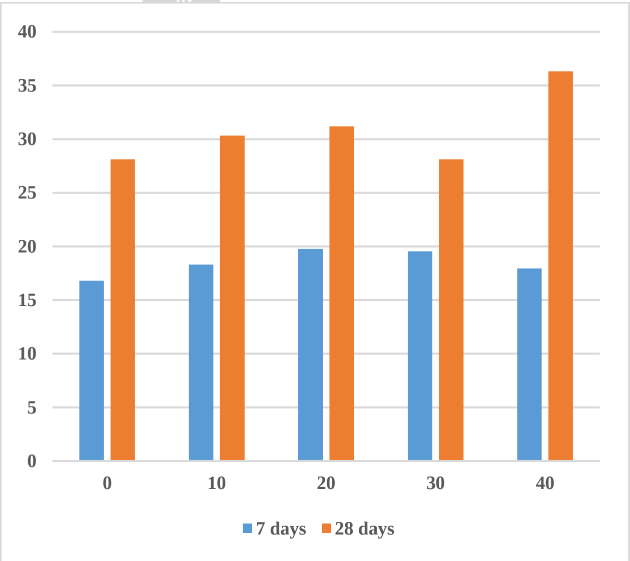

Fig 5: Comparison of compressive strength after 7 and 28 days

c) FLEXURAL STRENGTH TESTING OF CONCRETE

Test specimens of size 100 × 100 × 500 mm were prepared for determining the flexural strength of concrete. The

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concrete mixes were cast into standard beam moulds suitable for flexural testing. **Table: 7: Flexural strength of concrete**

S no.	Partial Replacement in %age	Ultimate Flexural strength 28 days (kN)
1	0	3.12
2	10	3.00
3	20	2.85
4	30	2.72
5	40	2.40

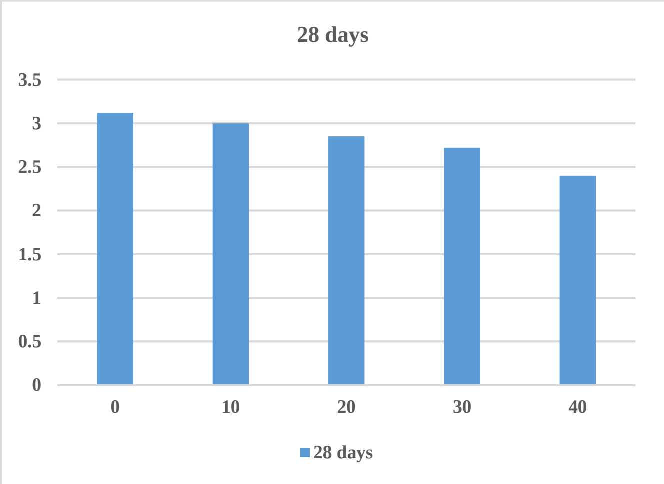

Fig 6: Flexural Strength after 28 days

d) SPLIT TENSILE STRENGTH

Concrete specimens in the form of cylinders measuring 150 mm in diameter and 300 mm in height were prepared for the evaluation of split tensile strength. For mixing, cement and fine aggregates were first dry-mixed to a uniform color, followed by the addition of coarse aggregates.

Table 8: Tensile strength of concrete

S no.	Partial Replacement in %age	Ultimate tensile strength 28 days (kN)
1	0	1.25
2	10	2.65
3	20	2.90
4	30	3.52
5	40	2.77

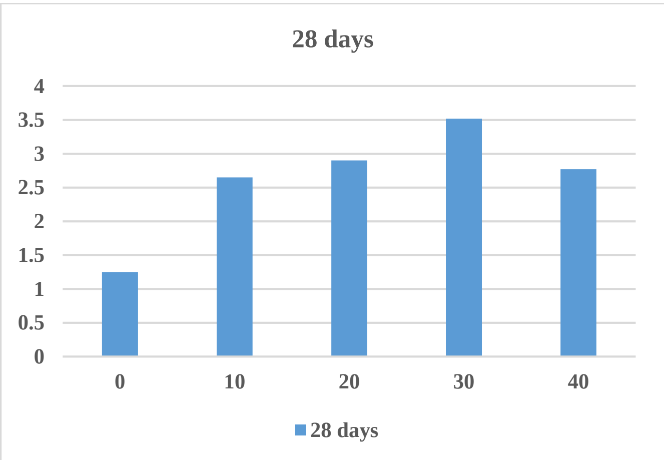

Fig 7: Tensile Strength after 28 days

V. CONCLUSION

The following conclusions could be drawn from the study:

a) Workability: The slump value of concrete exhibits a non-linear relationship with the percentage of Waste Paper Sludge (WPS) incorporated. At 0% WPS (S1), the slump is 100 mm, indicating high workability. Introducing 10% WPS (S2) reduces the slump to 85 mm, and at 20% WPS (S3), it slightly increases to 89 mm. However, a significant drop to 70 mm is observed at 30% WPS (S4), suggesting decreased workability. Interestingly, at 40% WPS (S5), the slump rises to 78 mm.

b) Strength: Concrete incorporating waste paper sludge (WPS) as a partial cement replacement demonstrates promising results. Replacing up to 30% of cement with WPS can enhance compressive strength, with 30% WPS mixes outperforming conventional concrete. At 40% replacement, strength remains comparable to traditional mixes. Strength and sulphate resistance improve with curing time. However, exceeding 30% WPS may reduce strength, necessitating careful mix design. Optimal WPS utilization offers sustainable, cost-effective concrete without compromising performance.

c) Optimum value: A 30% replacement of cement with waste paper sludge (WPS) in concrete offers an optimal balance between mechanical strength and environmental sustainability. At this level, compressive strength is maintained or even enhanced, while higher replacements may reduce strength. This approach also reduces cement usage, lowering carbon emissions and promoting sustainable construction practices.

VI. FUTURE SCOPE

The study's findings highlight the potential of paper sludge as a sustainable partial replacement for cement in concrete. Building upon these insights, several avenues for future research and application emerge:

1. **Durability Studies**: Investigate the long-term durability of concrete incorporating paper sludge under various environmental conditions, such as exposure to sulphates, chlorides, and freeze-thaw cycles.
2. **Optimization of Mix Designs**: Explore the optimal mix proportions for different construction applications, ensuring the best balance between strength, workability, and sustainability.
3. **Environmental Impact Assessment**: Conduct comprehensive life cycle assessments to quantify the environmental benefits of using paper sludge in concrete, including reductions in carbon emissions and conservation of natural resources.

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