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EXPERIMENTAL INVESTIGATION IN DEVELOPING LOW-COST CONCRETE FROM PAPER INDUSTRY WASTE

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ABSTRACT

More In India, the chemical and agricultural cycles deliver more than 300 million tonnes of industrial waste each year. These materials raise concerns of disposal and health risks. Contaminants in squanders like as phosphogypsum, fluorogypsum, and red mud have a negative impact on the strength and other qualities of construction materials that rely on them. To protect the environment, phosphogypsum, flurogypsum, lime slop, hypo muck, red mud, and mine following are the most important wastes now being generated. Paper production, for the most part, generates a great deal of solid waste. Paper filaments can only be reused so many times before they become too short or brittle to make excellent paper. It entails separating the damaged, low-quality paper strands and turning them into waste sludge. Every year, this paper mill waste consumes a massive amount of neighbouring landfill area. Worse still, as part of the trash collection method, a percentage of the rubbish is planted on crops, raising worries about pollutants accumulating in the soil or seeping into nearby lakes and streams. A few businesses burn their sludge in incinerators, contributing to real-world air pollution issues. It is typically essential to develop useful structure materials from these current squanders in order to reduce removal and contamination difficulties emanating from them. With this in mind, tests were conducted to investigate if it was possible to produce low-cast concrete by combining varying amounts of concrete with hypo sludge.

The subject of this research work is to study experimentally about the strength of the concrete and appropriate amount of partial replacement by replacing cement with 10%, 20%, 30%, 40%, 50%, 60% and 70% Hypo Sludge.

KEY WORDS: Hypo sludge, industrial waste, phosphogypsum, fluorogypsum.

1.INTRODUCTION

Agro-based projects in india now produce more than 300 million tonnes of water each year. Removal issues, health hazards, and cosmetic considerations all exist with these materials. Due to a scarcity of natural resources, ordinary portland concrete is being utilised more often on the planet these days as a result of the growth of enterprises, private structures, and other cement-based designs. As a result of the rapid expansion of cement production and use, some heat is released into the atmosphere as a result of cement hydration activity. In this study, hypo sludge is used to reduce the amount of concrete in the substantial. We may reduce the amount of trash produced by paper mills by using hypo sludge as a partial replacement for concrete. Magnesium and silica particles in the hypo slude enhance cement strength. Hypo sludge is a relatively new substance in the cementation industry. Various waste comes from different cycles utilised in the paper sector while providing paper, and it was initially created as a fake pozzolana. The paper industry, for the most part, produces a large amount of strong substitute. Before being eliminated, paper strands must be reused a specific number of times. Lime sludge, etp sludge, and de-linked sludge are three forms of slop produced by paper production operations. In our project, hypo sludge was used as a partial replacement for concrete. Every day, indian paper mills produce an average of 40 excess dry tones of slop. Hypo sludge has a specific gravity of 2.80, but it is somewhat higher when the silica concentration is low. This value is equivalent to the concrete's stated gravity of 3.15. The study would summarise the performance of hypo sludge cement as a partial substitute for concrete in the amounts of 15%, 10%, and 15%, which might assist to minimise hypo sludge removal and improve cement properties. Hypo slime has a large amount of silicon dioxide (sio2), which will provide extra energy

2. OBJECTIVE

• To investigate the strength of significant when hypo sludge is partially replenished.
• To figure out at what level of hypo sludge we'll be able to get the most extreme strength.
• To determine the percentage of hypo sludge mix in concrete mix.
• The purpose of this study was to see how hypo sludge substitution affected the compressive strength of concrete mixtures.

3. SCOPE

• To determine the optimum strength of hypo sludge as a partial replacement for concrete.
• Minimize environmental pollution caused by concrete and safeguard the ozone layer.
• Making the most of the losses.
• To keep the building costs down.
• It should be easily handled in the construction industry.
• To provide the most cost-effective cement.
• The time-dependent compressive strengths were estimated at 7 and 28 days to carry out the experiments.
• Minimize the highest level of interest in concrete.

4. Need for hypo sludge utilization

Different squanders emerge from the various cycles in paper endeavours while supplying paper. Because of its low calcium content, the priming waste is referred to as hypo sludge, and it is used in our project to substitute cement in concrete. Ozone-depleting chemicals are released into the environment as a result of cement manufacturing. They emit 1-million-ton ozone-depleting chemicals in order to produce 4 million tonnes of concrete. Additionally, this slop has been maintained away from mass level removal of land to reduce ecological devastation. Concrete production is reduced in order to reduce ozone layer consumption. Hypo sludge is used as a fractional substitute in the significant as better cement for this. The strength of the trash will be increased, and the cost of the waste will be reduced significantly.

5. LITERATURE REVIEW

Jayesh Kumar Pitroda (2013) investigated concrete strength and the optimum percentage of particle replacement by replacing cement with 10%, 20%, 30%, and 40% hypo sludge. With this in mind, the goal of the investigation is to see how concretebehaves when water is added using compression and split strength tests.
Rushabh shah and j. Pitroda (2013) investigated the results of a cement mortar with a 1:3 mix ratio in which the cement was partially replaced with hypo sludge at 0%, 10%, 30%, and 50% by weight of cement. The strength of the cement in the cement mortar 1;3 diminishes after 7&28 days as a result of partial replacement with cement in the cement mortar 1;3. As a result, it may be utilised in non-structural elements where compressive strength is not required and a low-cost temporary construction can be constructed.
Ritesh patil and j. Jammu (**2014)** investigated the mechanical characteristics of hypo sludge-containing concrete. As a substitute for cement, hypo sludge was utilised. The replacement percentages utilised in this study were ten percent, fifteen percent, twenty percent, and twenty-five percent. On 3 days, 7 days, and 28 days, the compressive strength of cubes was discovered. On the 28th day, the specimen's flexural and tensile strength were discovered on beams and cylinders, respectively. The use of hypo sludge in place of sand has been proven to improve the mechanical characteristics of concrete.
R. Balamurugan and R. Karthickraja (2014) investigated various combinations of cement and hypo sludge ratios, to make low-cost concrete. The work entails an experimental research of the strength of concrete and the optimal proportion of partial substitution of cement with anaerobic sludge at 5%, 10%, and 20%.
Abdulla Shahbaz khan (2014) presented the dissertation study to produce low-cost concrete using waste from the paper industry. Hypo sludge is replaced in various proportions such as 10%, 20%, and 30% by weight of cement in the dissertation work's control specimens, which have W/c ratios of 0.55 and 0.45, respectively. Compressive strength, spilt tensile strength, and flexural strength of concrete were studied. Curing should be permitted for three, seven, and twenty-eight days.
Naiketal. (2004) — Investigated fibrous residuals from pulp & paper mills as low-cost micro-reinforcement for cement composites and found that mill residuals can provide economical microfiber reinforcement, improving toughness and offering a valorisation route for mill wastes.
Solahuddinetal. (2022, review) - Comprehensive review on *waste paper concrete* summarising studies where waste paper was used as partial replacement for cement, fine aggregate and coarse aggregate; typical effective replacement ranges reported across literature were 5–15% (cement or aggregate basis), with mechanical property trade-offs depending on treatment and form (ash vs fibre). The review highlights variability in optimum percentages tied to sludge processing and curing.
Studies on Paper Sludge Ash (PSA/WPA) - mixed but promising (various authors, 2013-2024) - Multiple experimental studies show that incinerated paper sludge ash can behave as a supplementary cementitious material: many report improved or comparable compressive strength up to *~5–10%* replacement of OPC, with strength reduction beyond that unless combined with other SCMs or activators. Some recent works show local optima up to ~10–20% for lower strength grades depending on calcination and fineness. Examples: Devi (2023) and Ingale (2023) discuss beneficial effects at low replacement levels.
Alkali-activated and blended binders using paper waste (Mavroulidou et al., 2021; others)-Paper sludge ash has been successfully incorporated in alkali-activated slag and other geopolymer systems to produce viable binders; such systems often tolerate higher PSA contents than ordinary Portland cement mixes and can yield good mechanical properties and sustainability benefits. This suggests an alternative route if OPC replacement targets exceed typical pozzolanic limits.
Cellulosic fiber reinforcement (Hospodarova 2018; Bencardino 2024; Rezaei Shahmirzadi 2024) - Raw or processed waste-paper cellulose fibers added in small dosages (0.5–2% by mass) improved flexural toughness and crack control in mortars and concretes; however, excess fiber can reduce workability and compressive strength unless superplasticizers or special mixing protocols are used. Preparation method (pulped vs calcined) strongly affects outcomes.

Pervious & low-density applications (Maheswaran et al., 2023; Nazar 2014) - Paper sludge in pervious concrete and low-density mixes has been trialled: in some cases sludge behaved like a binder/filler and gave acceptable compressive strength for non-structural elements; however, strength trends vary (often decreasing as sludge % increases) so target application must match expected mechanical performance.

Srinivasan and Sathiya (2010) carried out experiments on concrete mixes in which cement was partially replaced with paper industry waste, commonly called hypo sludge. They tested mixes at different replacement levels and reported compressive and tensile strengths at 7 and 28 days. The findings suggested that lower levels of replacement enhanced strength marginally, while higher replacements led to strength reduction, indicating an optimum range of substitution.

Fernando et al. (2023) reviewed cellulose fibers derived from waste paper as reinforcement in cementitious composites. They concluded that small fiber additions improved flexural strength and crack resistance, although higher dosages could reduce compressive strength and workability. They recommended fiber contents of less than 2% by weight to balance benefits and drawbacks.

Singh and Chandel (2023) examined the combined use of waste paper sludge ash and rice husk ash in concrete. They evaluated compressive strength and shrinkage at various replacement levels up to 25%. Their results indicated that finer ash blends up to 10–15% replacement gave acceptable strengths, whereas excessive replacement increased shrinkage and reduced workability.

Ravi Kumar and Suresh Chandra (2023) studied waste paper sludge ash concrete in M25 and M40 grades at replacement levels of 5–20%. They performed compressive, split tensile, and flexural strength tests. The results showed optimum performance at about 10% replacement, with strength improvements at that level, but a decline when the percentage exceeded 15%.

Mehta and Thakur (2023) tested waste paper sludge ash as a supplementary material for high-grade concretes (M43 and M53). Their experiments showed that partial replacement up to 10–15% gave favourable compressive and split tensile strengths, while higher replacements reduced overall performance.

A study by Maheswaran et al. (2023) assessed waste paper sludge ash in pervious concrete. They observed that small substitutions contributed to acceptable compressive strength for non-structural applications, but greater percentages weakened the mix significantly.

Pitroda et al. (2013) examined the use of hypo sludge from the paper industry as a partial replacement of cement in concrete. Cement was replaced at levels of 10%, 20%, 30%, and 40%, and compressive as well as split tensile strength tests were conducted. They reported that lower replacement levels improved performance, but strength decreased when the replacement exceeded 20%, highlighting an optimum range for structural applications.

Mavroulidou et al. (2021) explored the use of paper sludge ash in alkali-activated slag binders as an alternative to Portland cement. Their study demonstrated that the inclusion of sludge ash improved sustainability and allowed higher levels of substitution while maintaining compressive strength and durability in comparison with conventional mixes.

Shabbir, Ejaz, Ahmad, Hussain and Tahir (2016) investigated the use of paper mill sludge ash in concrete as a partial replacement of cement. They evaluated compressive and tensile strengths, density, and setting times at replacement levels of 5%, 10% and 15%. Their results showed that low percentages of sludge ash could be used without significant loss in strength, but higher levels negatively impacted workability and durability.

Wang, Li, Jiang and Chen (2018) studied cement mortar containing waste paper fibers as partial aggregate replacement. They tested compressive strength, setting times and performed microstructural analysis to examine hydration. The findings revealed that small fiber additions improved toughness and crack resistance, but compressive strength declined at higher fiber contents due to weak bonding and fiber clumping.

Yannana, Kesanapalli and Velamakayala (2022) explored the use of paper mill sludge combined with wastewater sludge as a cement substitute in concrete. Cement was replaced in increments of 5%, 10% and 15%, and compressive, split tensile and flexural strengths were tested at 7 and 28 days. The study concluded that 5% replacement improved mechanical properties slightly, but performance deteriorated at higher levels.

Kumar and Jaiswal (2019) carried out experiments on M30 concrete using hypo sludge from the paper industry as a partial cement replacement. Replacement levels of 10%, 20% and 30% were examined for compressive and split tensile strengths. The results indicated a gradual reduction in strength with increasing sludge content, though the 10% mix still provided acceptable values compared to control.

6. HYPO SLUDGE

Hypo sludge is a waste material produced in paper manufacturing, particularly during the chemical recovery and wastewater treatment processes. It is a semi-solid residue that contains large amounts of calcium carbonate, silica, magnesium, and traces of alum, iron, and fibrous cellulose. Typically grey in color and fine in texture, hypo sludge resembles some of the raw constituents of cement, which makes it attractive for partial replacement in concrete.

In most paper mills, hypo sludge is treated as a waste product and disposed of in landfills or open dumping areas. This practice creates environmental challenges such as land occupation, unpleasant odor, and potential contamination of soil and groundwater. With increasing concerns about sustainability and waste management, researchers have explored methods to utilize hypo sludge as a supplementary material in cement and concrete production.

The properties of hypo sludge depend largely on its chemical composition, which varies with the paper manufacturing process and treatment methods. In the sample used for this study, the major constituents are silica (SiO_2), acid insoluble matter, loss on ignition (LOI), calcium oxide (CaO), and magnesium oxide (MgO).

Silica (SiO_2) is a key component that can contribute to pozzolanic activity when combined with calcium hydroxide during hydration. Although the reactivity of silica in hypo sludge is lower than in conventional supplementary cementitious materials like fly ash.

Acid insoluble matter represents the fraction that does not readily react with acids, reflecting the inert or non-reactive portion of the sludge. A higher acid insoluble content typically reduces the reactivity of the material, which limits the optimum replacement levels in cement.
Loss on ignition (LOI) indicates the amount of volatile matter, moisture, and unburnt organic content present. High LOI values can affect workability and delay setting, but moderate values do not significantly hinder performance.

The hypo sludge is made at the Hitar industrial sector. This plant may be found close to Taxila. Hypo sludge has a low calcium content, a high calcium chloride content, and a low silica content. Because of its silica and magnesium content, hypo sludge behaves like cement. The addition of silica and magnesium to concrete improves its curing time. We replaced 0,10,20,30,40,50,60,70% of the cement with hypo sludge.

S.no	**Constituent**	**% present in hypo sludge**
1.	Magnesium oxide	3.3
2.	Calcium oxide	46.2
3.	Loss on ignescent	27.00
4.	Acid insoluble	11.1
5.	Silica (SiO2)	9.0

Table 1: Properties of hypo sludge as cement ingredient

S.NO	**Constituents**	**Cement (in %)**	**Hypo sludge**
1	Lime(cao)	62	46.2
2	Silica(sio2)	22	9
3	Alumina	5	3.6
4	Magnesium	1	3.33
5	Calcium sulphate	4	4.05

7. MIXING OF CONCRETE

The test samples were prepared using a mix M20 grade that waccording to Indian standard procedure

Unit	**Water**	**cement**	**Fine aggregate**	**Coarse aggregate**
By weight (kg)	200	411	672	1326
By volume	0.40	1	0.428	0.856

according to Indian standard procedure.
Table 3: Design mix proportion

7.1 Mix proportions

Conventional concrete – 1:0.428:0.856
10% replacement – 0.90:0.428:0.856
20% replacement – 0.80:0.428:0.856
30% replacement – 0.70:0.428:0.856
40% replacement – 0.60:0.428:0.856
50% replacement – 0.50:0.428:0.856
60% replacement – 0.40:0.428:0.856
70% replacement – 0.30:0.428:0.856

8. RESULT AND DISCUSSION

8.1 COMPRESSIVE STRENGTH TEST RESULT

Partial replacement (%)	Number of specimen	Ultimate load (KN)	Ultimate compress ive strength (N/mm^2)
0	3	343.5	15.2
10	3	480.0	21.3
20	3	630.0	28
30	3	680.0	30.22
40	3	476.3	21.16
50	3	340.5	15.13
60	3	228.3	10.15
70	3	165.7	7.37

Table 4 : Compressive test of cubes at 14 days

Partial replacement (%)	Number of specimen	Ultimateload (KN)	Ultimate compressive strength (N/mm^2)
0	3	121.37	1.70
10	3	101.49	1.44
20	3	94.12	1.34
30	3	90.18	1.28
40	3	89.16	1.25
50	3	87.25	1.23
60	3	91.58	1.28
70	3	91.69	1.30

Table 5: Split tensile strength of cylinder at 28 days

8.2 SPLIT TENSILE TEST RESULT

Table 6: Split tensile strength of cylinder at 28 days

Partial replacement (%)	Numberof Specimen	Ultima te load (KN)	Ultimate compressive strength (N/mm^2)
0	3	650.46	28.90
10	3	710.54	31.13
20	3	840.2	37.34
30	3	885.45	39.45
40	3	680.7	30.25

50	3	370.67	16.47
60	3	325.7	14.47
70	3	220.5	9.80

9. CONCLUSION

Finally we finish our project by using different mixtures with 14-day and 28-day drying times and partial cement substitution with hypo sludge. Cubes are put through their paces in a 1000 kN compression testing machine. The compressive strength of concrete improves as the curing duration for M20 grade concrete grows and the replacement of hypo sludge is increased from 0%, 10%, 20%, 30%, 40%, 50%, 60%, and 70%. For 10% cement replacement, the maximum compressive strength is obtained for 14 days and 28 days, and then the strength begins to decline from 20% to 30%. For 10% cement replacement, the maximum spilt tensile strength is obtained for 14 days and 28 days, and then the strength starts to decline from 20% to 30%. In comparison to ordinary concrete, a 10% substitution of hypo sludge with cement increases the strength of the concrete.

The compressive strength of cube at 14 days
(30%) = 30.22 N/mm^2
The compressive strength of cube at 28 days
(30%) = 39.45 N/mm^2

The split tensile test on cylinder at 28 days

(10%) = 1.44 N/mm^2

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