

# An Experimental Study on the Effective Utilization of Hypo Sludge in Fiber Reinforced Concrete

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**Abstract** — The disposal of industrial waste such as paper mill sludge (hypo sludge) has become a serious environmental concern due to limited landfill space and high disposal costs. Hypo sludge contains high calcium content and exhibits pozzolanic properties, making it a potential partial replacement for cement in concrete. This experimental study investigates the mechanical performance of Fiber Reinforced Concrete (FRC) incorporating hypo sludge at varying replacement levels of cement (0%, 5%, 10%, 15% and 20%) along with steel or polypropylene fibers (0.5% and 1% by weight of cement). Tests conducted include compressive strength, split tensile strength, flexural strength and durability evaluation. The results indicate that concrete with 10% hypo sludge and 0.5% fibers provides optimum strength compared to conventional concrete, whereas higher replacement levels decrease strength due to reduced cementitious content. The study demonstrates that hypo sludge can be effectively used in FRC to reduce cement consumption, minimize waste disposal problems and enhance sustainability in construction.

**Keywords:** Hypo Sludge, Fiber Reinforced Concrete, Industrial Waste, Compressive Strength, Tensile Strength, Sustainability, Paper Mill Sludge

## I. INTRODUCTION

The construction industry is continuously seeking environmentally friendly and cost-effective alternatives to ordinary Portland cement (OPC). The cement manufacturing sector is highly energy-intensive and responsible for significant CO<sub>2</sub> emissions. Therefore, partial replacement of cement with industrial waste materials has become a major research focus. Hypo sludge is a waste generated from the bleaching process in paper mills, containing calcium chloride, magnesium, silica, and very low organic content. Due to the presence of slow-reacting lime, hypo sludge exhibits pozzolanic behavior which can contribute to strength development in concrete. However, its mechanical performance becomes limited beyond optimum levels.

Fiber reinforcement in concrete provides additional tensile and crack resistance and improves post-cracking performance. Combining hypo sludge with fibers may enhance both economic and mechanical benefits. This study evaluates the effect of hypo sludge and fibers on the strength properties of concrete.

## II. LITERATURE REVIEW

1) V. Rajasekar and D. Kumar (2022) tested slump and compressive strength on fiber-reinforced concrete and reported that workability decreased with fiber addition but strength increased.

- 2) R. Balaji and M. Subramani (2022) found that the addition of steel fibers improved ductility and crack control while combining hypo sludge reduced shrinkage.
- 3) Santosh Kumar and P. Pawar (2023) analyzed mechanical properties of hypo sludge concrete for sustainable construction and found significant environmental cost savings.
- 4) S. Banerjee and P. Ghosh (2023) concluded that fiber reinforcement compensated for strength loss at higher replacement levels of hypo sludge.
- 5) R. Srinivasan and K. Sathish (2023) suggested using hypo sludge in precast blocks and lightweight structures due to improved durability and reduced density.
- 6) N. Murthy and L. Patel (2024) investigated the combined use of fly ash and hypo sludge in concrete and observed synergistic effects by improving strength and reducing carbon footprint.

## III. OBJECTIVE

- 1) To evaluate the feasibility of using hypo sludge as a partial replacement for cement in concrete.
- 2) To investigate the mechanical properties of FRC containing hypo sludge at different replacement levels.
- 3) To determine the optimum percentage of hypo sludge and fibers for maximum strength performance.
- 4) To contribute towards sustainable solid-waste management solutions for paper industries.

## IV. RESULTS AND DISCUSSIONS

### A. Slump test

The slump test is a simple and widely used method to measure the workability or consistency of fresh concrete. It helps to determine how easily concrete can be mixed, placed, and compacted without segregation. Here's a detailed explanation:

Purpose

- To determine the workability of fresh concrete.
- To ensure uniformity between batches.
- Helps in assessing the fluidity of the mix

The results of the slump test, which was used to determine the workability of each mix, are shown in figure

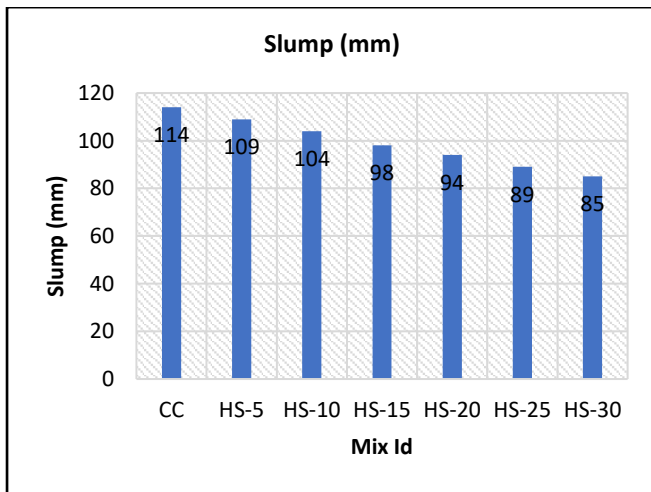


Fig. 1: Slump variation of hypo sludge concrete with control concrete

The testing findings indicated that the slump value of the control concrete (CC) was 114 mm. The incorporation of hypo sludge resulted in a decrease in workability between 5% and 30%, dependent upon the degree of replacement. When hypo sludge was used for complete replacement, the slump value decreased markedly in comparison to the control concrete. The diminished workability is mostly because to the porous characteristics of hypo sludge, resulting in a significant water absorption capacity. As the percentage of hypo sludge in the concrete mixture escalates, the water requirement concurrently climbs, hence diminishing workability. Ahmad et al. (2013) reported similar findings. The reduction in slump may be ascribed to the increased surface area of hypo sludge, necessitating more water to envelop the particles.

### B. Compressive strength

Compressive strength is the maximum load per unit area that concrete can withstand without failing under compression. It is usually expressed in megapascals (MPa) or N/mm<sup>2</sup>.

In order to optimize the percentage of hypo sludge, an initial investigation into compressive strength testing was conducted on 150x150x150mm cube specimens with 0%, 5%, 10%, 15%, 20%, 25%, and 30% hypo sludge as a cement replacement material

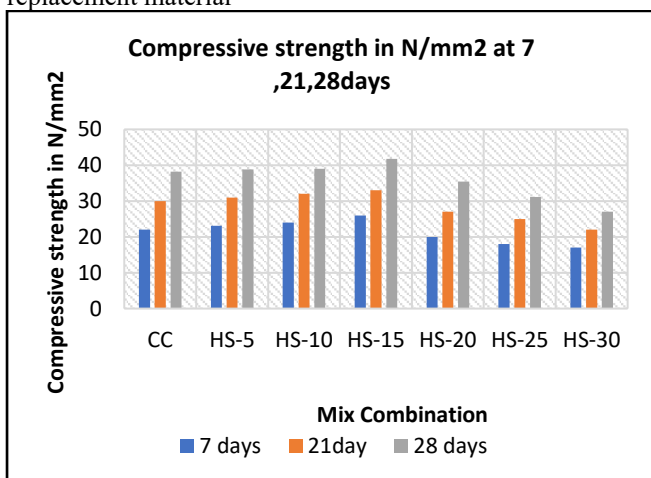


Fig. 2: Compressive strength in N/mm<sup>2</sup> at 7, 21, 28 days

The mixture with 15% substitution of hypo sludge yielded the highest compressive strength, as seen in the figure above. The presence of hypo sludge occupying significant voids in the control concrete may account for this phenomenon. Nonetheless, the porosity of anaerobic sludge resulted in concentrations over 15% adversely affecting the concrete's strength owing to pore formation; similar findings have been reported by other studies. The incorporation of hypo sludge enhances compressive strength by pozzolanic activity. The specimen containing a 15% incorporation of hypo sludge in the concrete exhibits a compressive strength of 43.20 MPa, representing a 10.26% increase compared to the control concrete.

### V. CONCLUSION

The workability of the concrete was further lowered upon the addition of basalt fiber. When more polymer is added, the workability of the concrete increases because the polymer has a lubricating effect that makes the new concrete mix more fluid and because the liquid polymer lowers the frictional force between the concrete mix, increasing the workability of the concrete.

The results indicate that incorporating the material up to 15% (HS-15) enhances compressive strength, while further increases beyond this level lead to a reduction in strength. Thus, HS-15 can be considered the optimum mix proportion for achieving maximum compressive strength.

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