

# Effective Utilization of Hypo Sludge, SBR Latex and Basalt Fibre in Concrete

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## Abstract

To minimize the environmental pollution and to utilize the wastes as suitable raw materials in concrete, hypo sludge is identified as the sustainable alternative material for the substitution of conventional construction materials. This paper is designed to investigate the inclusion of hypo sludge as supplementary cementitious material (SCM) and the influence of hypo sludge on the mechanical and durability of the concrete mix made with different cement replacement levels and to investigate the influence of basalt fibre and Styrene-Butadiene rubber latex (SBR) on the strength and durability properties of hypo sludge concrete and to examine the flexural behaviour of optimized latex-modified basalt fibre reinforced hypo sludge concrete. The addition of basalt fiber by 0.3%, with 10% of SBR latex in hypo sludge concrete improved the mechanical, durability properties and flexural behaviour of concrete.

**Keywords:** basalt fiber; hypo sludge; SBR latex; sorptivity; energy dispersion; ductility

## 1. INTRODUCTION

Concrete is the most versatile artificial construction material, extensively used for many sorts of activities (Regupathi et al. 2025). During the manufacturing of cement, it emits carbon dioxide (CO<sub>2</sub>) (Which is around 7% of the total global CO<sub>2</sub> emissions) and other greenhouse gases, which causes many environmental and health hazards and has a negative impact on global warming.

To minimize the pollution due to emission of gases effective measures should be taken (Kumar et al. 2024). On the other side, the solid wastes from various industrial sectors cause many environmental and health hazards and the accumulations of solid wastes from various industries are increasing rapidly (Prakash et al. 2019; Prakash et al. 2020). Disposal of waste materials is challenging task and sustainable solution is needed for the effective disposal of industrial waste. Significant study has been done on the creation of innovative building materials from diverse solid waste types from different sectors (Pattusamy et al. 2023). Nevertheless, there is not much use of these building materials in actual construction. To support their practical uses, more research is required to examine the real behaviour or performance of solid waste-based construction materials in field settings (Ravikumar et al. 2024). There is potential for new building components to be introduced using alternative construction materials made from industrial solid wastes, which could somewhat lower the cost of construction (Ravikumar et al. 2023).

During the production of paper, numerous types of waste are generated and these wastes eventually get

dumped in the local landfill (García et al. 2008). Using the current global waste-to-wealth growth strategy, waste from pulp and paper mills can be turned into a variety of construction materials. Various investigations were conducted to substitute cement with different industrial byproducts with pozzolanic characteristics as supplemental cementitious material (Shanmugasundaram et al. 2023; Alnahhal and Aljidda 2018). Garcia et al. researched the potential applications of solid wastes (hypo sludge) from the paper industry as fine aggregates, coarse aggregates, or extra cementing material in the manufacturing of construction materials. Because of its diminished ductility and durability, hypo sludge's application in concrete was restricted. To overcome the diminished ductility, fiber-reinforced composites, especially the basalt fibers have become a formidable rival over the past ten years (Farid and Kadhim 2016). Compared to carbon fiber, basalt fibers are substantially more affordable and have superior mechanical qualities than glass fiber. Its growing use across a range of sectors is hence one of the key elements propelling the market's expansion (Balwaik and Raut 2011).

To increase flexural strength, bonding, and durability, Styrene Butadiene Rubber (SBR) latex is extensively used in these days to concrete, cement mortar, and cement slurry. To validate the positive impacts of solid wastes with fibers on the essential characteristics and robustness of new building materials, more study is necessary. Therefore, the purpose of this research is to investigate the effects of basalt fibre on post-cracking behaviour and SBR Latex on the durability of hypo-sludge concrete, while also using hypo-sludge as a partial replacement for cement. The mechanical and durability properties of latex-modified basalt fibre reinforced concrete are the main focus of the current study as a result of partial cement replacement with hypo sludge.

## 2. Objectives

- To investigate the inclusion of hypo sludge as supplementary cementitious material (SCM) and the influence of hypo sludge on the mechanical and durability of the concrete mix made with different cement replacement levels.
- To examine the optimum percentage of basalt fibre and SBR latex in hypo sludge-based concrete. To investigate the influence of basalt fibre and SBR latex on the strength and durability properties of hypo sludge concrete.
- To examine the flexural behaviour of optimized latex-modified basalt fibre reinforced hypo sludge concrete.

## 3. Incorporation of Hypo Sludge, Basalt Fibres, and SBR latex

This paper aims to provide the findings of novel research on the effectiveness of additive materials on the performance of concrete by conducting an experimental study of concrete using hypo sludge as a partial replacement of cement with the addition of basalt fiber and SBR Latex. For experimentation, various combinations have been arrived with varying usage dosages of hypo sludge of 5%, 10%, 15%, 20%, 25%, and 30% by weight replacement of cement (Chandra Sekar et al. 2023). In addition to the hypo sludge, basalt fiber is added in increasing quantities to increase the mechanical performance of the concrete: 0.10%, 0.2%, 0.3%, 0.4%, and 0.50% by volume of concrete. Because the water absorption rate was significant, SBR latex was added in proportions of 5%, 10%, 15%, and 20% by weight of cement to increase the durability and flexural performance of the hypo sludge concrete (Table 1-4). Fresh, mechanical, durability, micro structural characteristics, and flexural behavior of hypo sludge

concrete reinforced concrete beams were studied. SEM examination was used to assess the hypo sludge's shape, while XRD and FTIR were used to identify the phase and characterize the molecules.

**Table 1. Physical properties of Hypo sludge**

Property	Values
Specific Gravity	2.69
Specific surface area (cm <sup>2</sup> /g)	2895
Initial setting (min)	38

**Table 2. Hypo sludge-Chemical composition**

Oxides	Tested Value (%)
Lime	27.03
Silica	20.56
Iron oxide	26.74
Alumina	19.35
Magnesium oxide	6.32
Loss of ignition	3.04

Basalt fibers of 18 mm in length and 13 µm in diameter were used in this study. In order to ascertain the ideal amount of fiber content in hypo sludge concrete, basalt fiber was added at volumes of concrete corresponding to 0.10%, 0.2%, 0.30%, 0.4, and 0.50%. The waste product (hypo sludge) is derived from the paper industry, which causes it to absorb more water and lose durability.

**Table 3. Properties of Basalt Fibre**

Sl. No	Parameters	Value
1	Density(kg/m <sup>3</sup> )	2800
2	Moisture content (%)	<0.3
3	Melting point (°C)	1350
4	Diameter (µm)	13
5	Length(mm)	18
6	Tensile Strength (MPa)	3000
7	Alkali resistance	High
8	Ignition point	High
9	Thermal conductivity	Low

**Table 4. Properties of SBR latex**

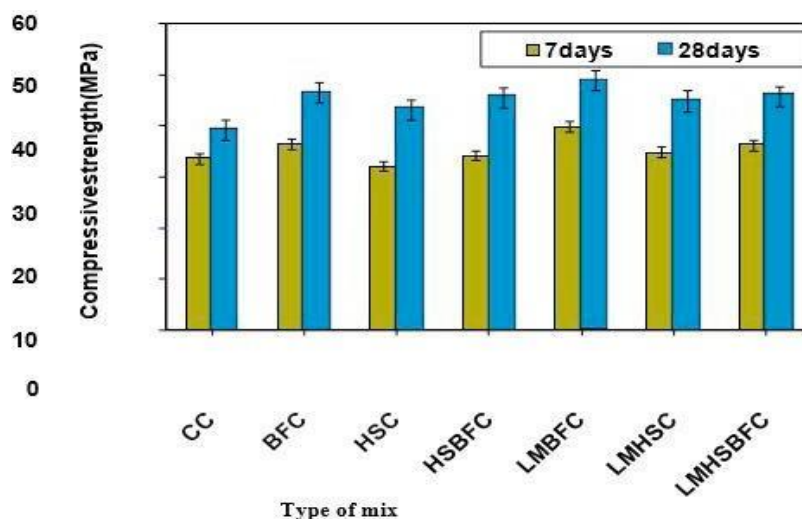
Sl. No	Property	Value
1	Styrene content (%)	34±1.5
2	Butadiene content (%)	66±1.5
3	Density (g/mm <sup>3</sup> )	1.03
4	Color	White
5	pH	11

When concrete is subjected to severe loading conditions, it deteriorates and loses its structural integrity, serviceability and safety. Permeability, concrete cracking, low chemical resistance, low abrasion

resistance, an inadequate cover of steel reinforcement, and the overall general quality of structural concrete are the main elements that promote the transport mechanism of aggressive agents like chlorides and sulphate into structural concrete. On the other hand, adding hypo sludge to concrete reduces its workability and requires more water. Therefore, in order to give adequate workability and significantly higher, a water reducer (such polymers) must be used to increase the modified concrete mix's workability. They also improve the workability of concrete mixes by postponing Portland cement's setting and hydration). Therefore, the purpose of this study is to increase the durability of hypo-sludge concrete by using Styrene Butadiene Rubber.

#### 4. Investigation on Fresh and Hardened Concrete

To determine the workability standards for each mixture, the slump cone test was performed on fresh concrete. Numerous mechanical characteristics, including flexural strength, split tensile strength, compressive strength, and durability characteristics including sorptivity, water absorption, and the rapid chloride penetration test, have been studied. In latex modified basalt fiber reinforced concrete flexural members, the experiment was carried out to determine whether hypo sludge may be used in place of particular cement. In total, 14 different sized beams were cast and subjected to testing under both static and cyclic loads. ANSYS software was used to validate the flexural behavior once it was examined. After 28 days, the concrete with 15% hypo sludge used to replace cement and with basalt fiber (HSBFC) had a compressive strength of 45.56MPa, which is 16.28% higher than the control concrete (CC). After 28 days of curing, concrete with 15% hypo sludge and SBR latex (LMHSC) had a compressive strength of 44.95MPa, which was 14.73% higher than CC. The concrete that received 15% hypo sludge substitution for cement, basalt fiber, and SBR latex (LMHSBFC) at 28 days had a 17.08% higher compressive strength of 45.87 MPa than the control concrete.



**Fig. 1. Compressive strength test result of all mis at 7 and 28 days**

The split tensile strength of concrete with 15% hypo sludge addition (HSC) was 3.68MPa, which is 9.52% greater than that of CC. The concrete which included basalt fiber and 15% hypo sludge usage has shown a split tensile strength of 3.7 MPa, which was effectively 10.12% higher than CC. Similarly, concrete with 15% hypo sludge and SBR latex exhibited a tensile strength of 3.71MPa after 28 days of curing, which is 10.42% higher than CC. At 28 days, the tensile strength of the concrete containing 15% hypo sludge instead of cement, basalt fiber, and SBR latex was 3.98MPa, 18.45% greater than that of the

control concrete. With 15% hypo sludge substitution, the concrete's flexural strength was 5.6 MPa, 6.67% higher than that of CC. After 28 days, the flexural strength of the concrete with 15% hypo sludge substitution and basalt fiber was 5.69MPa, 8.38% higher than that of CC. The flexural strength of concrete with 15% hypo sludge and SBR latex was 5.85 MPa, 11.43% higher than CC. After 28 days, the concrete with 15% hypo sludge, basalt fiber, and SBR latex had a flexural strength of 6.05MPa, which was 15.24% higher than the control concrete. The latex modified basalt fiber reinforced hypo sludge concrete can improve both early and later concrete strength when compared to the control concrete. The enhanced strength (CH) can be attributed to the filler effect of hypo sludge as well as its pozzolanic reactivity with cement hydration process byproducts such as calcium hydroxide. Strengthening is also a result of the polymer layer that forms and fills in most of the pores in concrete. The concrete's bond strength decreased by 15.3% and 11.6% when 15% hypo sludge was substituted for cement. The binding strength between steel and concrete for LMHSBFC was enhanced by the addition of basalt fibre and SBR latex to hypo sludge concrete, achieving 16.9 MPa on average, a 19.39% improvement over the control concrete (CC) mix. The latexcoating strengthens the bond between the materials when flexural or tensile loading is applied to the concrete. The importance of these modified concrete combinations has increased due to the necessity for long-term construction and environmental preservation.

## 5. Micro Structural Studies

SEM technology allows for both qualitative description of the qualities of the concrete. Scanning electron microscopy observations reveal the incredibly porous nature of hypo sludge particles. Hypo sludge's porosity could make concrete harder to work with by increasing the need for plasticizers and water. The SEM image that was visually evaluated reveals that the concrete that has been treated with basalt fiber and SBR latex differs significantly from the other mixes in terms of its pore structure. The SBR latex layer and the hypo sludge pozzolanic action helped to refine the void size in contrast to the control concrete. This microstructure development leads to an improvement in the mechanical and durability qualities of concrete. The results of this investigation demonstrate that adding hypo sludge decreases fresh concrete's workability. Utilizing SBR latex as a water reduction agent is necessary to increase the workability of freshly laid concrete. The addition of hypo sludge and SBR latex to concrete enhances its mechanical and durability qualities due to their impact on the microstructure of the concrete and the fine tuning of the pore volume. The size of the voids and their interconnectivity also alter as a result of this. The improvement in the concrete structure can be due to the filler effect of hypo sludge and SBR latex with cement hydration products such as calcium hydroxide CH, which produce more CSH and increase the density and decrease the porosity of the concrete. Moreover, the development of a polymer film has the potential to completely fill in concrete's pores. The addition of anaerobic sludge enhanced the concrete's interfacial contacts, according to micro structural research. Due to the creation of a film layer by SBR latex in the cement matrix and a decrease in the concrete's ITZ, the mix LMHSBFC exhibited a homogeneous and denser microstructure when compared to the control concrete.

## 6. Flexural Behaviour of R.C. Beams

The latex modified basalt fiber reinforced concrete (LMBFC) and LMHSBFC specimens exhibit superior performance characteristics in both static and cyclic loading behavior as compared to the reinforced concrete control beams (CC). For LMBFC specimens and LMHSBFC specimens, the first RC beam crack occurs under static loading at a load of 18 kN and 15 kN, respectively; under cyclic loading,

the first RC beam crack occurs under a load of 25 kN and 21 kN for LBFC and LMHSBFC specimens, respectively. In comparison to the conventional reinforced concrete beam CC, the LBFC beam specimen's ultimate load carrying capacity rose by 23.73% under static loading, while the LHSBFC specimens' load carrying capacity increased by 5.08%. Under cyclic loading, the hypo sludge concrete with basalt fiber and latex LMHSBFC beam specimen's ultimate load carrying capacity increased by 18.18% over the conventional reinforced concrete beam CC, while the latter's load carrying capacity increased by 1.82%. The ductility of beam LMHSBFC increased by roughly 3.97%, whereas that of LBFC beam specimens increased by 10.11% under static loading (Table 5). The ductility of specimens of LBFC and LHSBFC beams increased by 41.74% and 21.84%, respectively, during cyclic stress. In comparison to the control concrete beam, the stiffness of the LBFC beam specimen rose by 16.8% under static loading, while the LMHSBFC beam's stiffness increased by roughly 7.6%. When exposed to cyclic loading, the ductility of beam specimens made of LBFC increased by 15.68%, whereas that of beams made of LMHSBFC increased by 2.69%.

### 7. Compatibility between Experiment and Finite Element Simulation

Although there was a considerable degree of agreement between the FEA and the test results, it was noted that the FEA projected outcomes that were nearly greater than the experimental data. For static loading, the highest load error in prediction is 8.71%, and for cyclic loading, it is 8.95%. The comparison has produced good agreement. The FEM- based analytical study demonstrates that it was in strong agreement with the experimental study. Because LMHSBFC provides equivalent load carrying capacity, superior ductility, and improved energy dissipation when compared to control concrete beams under static and cyclic loading, it can therefore be used to manufacture sustainable concrete structural members in regions with a moderate seismic risk.

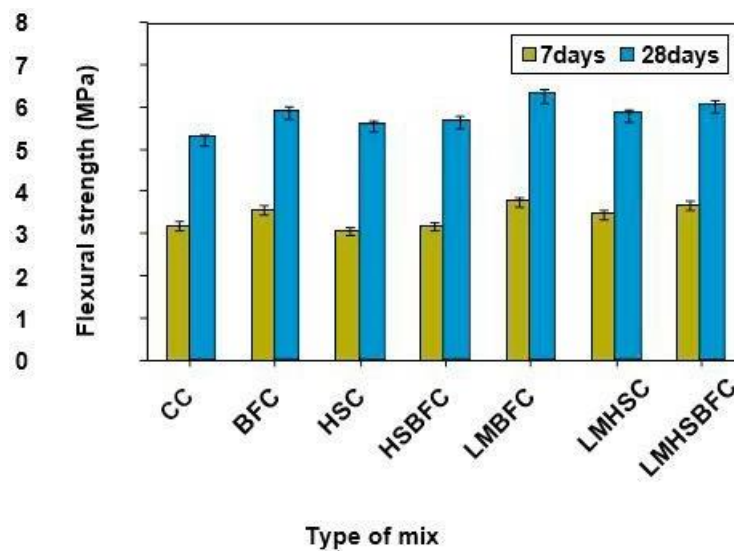
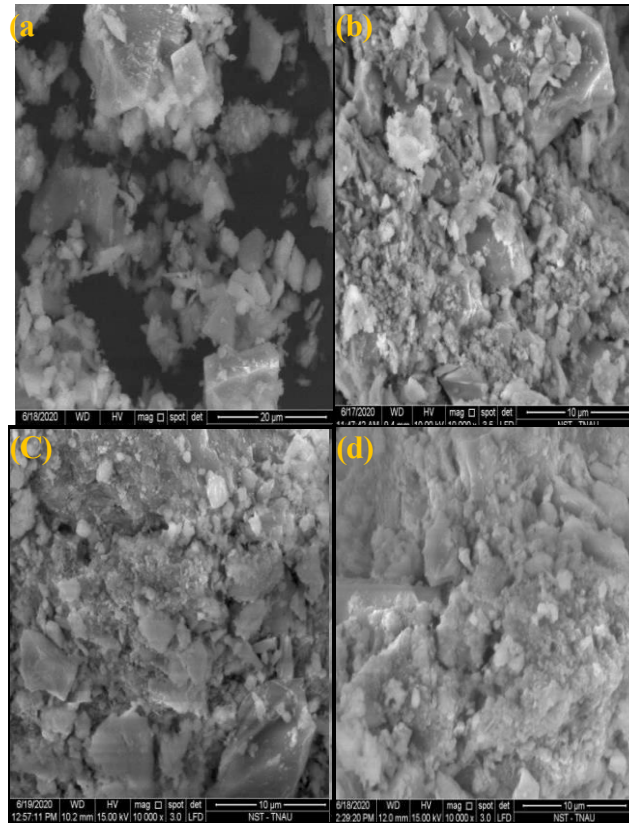


Fig. 2. Flexural strength test results of all mix



**Fig. 3. SEM images a) CC b) LMHSC c) LMBFC d) LMSBFC**

**Table 5. Load and deflection behavior of beams under static loading**

Beam ID      First crack load (KN)  
 $P_{cr}$   
 First crack deflection (mm)  
 $\Delta_{cr}$   
 Ultimate load (KN)  
 $P_{ult}$   
 Ultimate deflection(mm)  
 $\Delta_{ult}$   
 Failure Load (KN)  
 $P_{failure}$

**Max deflection (mm)**

						$\delta_{max}$
CC	15	1.80	64	14.50	47	23.00
HSC	9	1.03	60	12.33	49	20.43
BFC	18	1.89	76	14.79	49	24.50
HSBFC	12	2.03	66	15.43	52	24.83
LMHSC	15	2.14	67	14.47	52	24.57
LMBFC	21	3.10	81	16.02	54	24.4
LMHSBFC18		2.60	70	15.04	57	23.33

## 8. Conclusion

With the addition of basalt fibers and latex, investigated the potential of using paper waste sludge as a partial replacement for cement in concrete toward a more sustainable and ecofriendly construction material. The addition of basalt fiber by 0.3%, with 10% of SBR latex in hypo sludge concrete improved the mechanical properties of concrete. Addition of hypo sludge in concrete reduced the durability of the concrete. It has been overcome by adding SBR latex in concrete mixes. With addition of BF and SBR latex, the mix LMHSBFC shows reduced water absorption, permeability and penetration of chloride ions, improved durability of concrete compared to control concrete. The performance of beam specimen with SBR latex and basalt fiber in hypo sludge concrete has improved. Hence it can be concluded that LMHSBFC can be used as a sustainable concrete structural member in moderate seismic risk regions as it gives comparable load carrying capacity, better ductility and energy dissipation when compared to the control concrete beams. The effective content of basalt fibre and SBR latex contributes to the enhancement of the mechanical and structural properties of hypo sludge concrete, as well as a new feasible approach for expanding engineering applications. The study is useful for the production of composite building materials with low thermal conductivity from wastes, which would be an innovative solution that will resolve both energy and environmental concerns

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