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Enhancing Concrete Durability through Partial Replacement of Cement with Hypo Sludge

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Abstract

Concrete is the most widely used construction material worldwide, and cement is the most critical component of concrete. The production of cement is energy-intensive and produces a significant amount of CO2 emissions. One solution to reduce the environmental impact of concrete production is by using supplementary cementitious materials such as Hypo sludge. Hypo sludge is an industrial waste product that is produced during the manufacture of paper. This research investigates the durability characteristics of concrete with partial replacement of cement by Hypo sludge. The research involves casting and curing of specimens, testing the durability of specimens, and comparing the results with traditional concrete. The results of the research show that partial replacement of cement by Hypo sludge can improve the durability of concrete, which makes it a viable alternative to traditional concrete.

Keywords: *Durability, Concrete, Hypo sludge, Cement, Replacement*

INTRODUCTION

Concrete is one of the most widely used building materials in the world. It has been used for centuries because of its durability, strength, and ability to withstand harsh environmental conditions. However, the production of concrete requires a large amount of cement, which is a major contributor to greenhouse gas emissions. Moreover, the disposal of cement waste is a significant environmental concern.

To address these issues, researchers have been exploring the use of alternative

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materials, such as industrial waste by-products, to partially replace cement in concrete. One such by-product is hypo sludge, which is generated from the paper manufacturing industry. This paper aims to provide an overview of the properties of hypo sludge, its suitability as a cement replacement material, and the effect of its use on the durability of concrete.

Properties of Hypo Sludge:

Hypo sludge is a by-product of the paper manufacturing process, which is generated when paper is bleached with sodium hypochlorite. It is a fine-grained material with a high silica content, and its chemical composition is similar to that of pozzolanic materials such as fly ash and silica fume. Hypo sludge is also rich in calcium and aluminum, which makes it a suitable material for use in cement-based products.

Suitability of Hypo Sludge as a Cement Replacement Material:

Hypo sludge can be used as a partial replacement for cement in concrete. The addition of hypo sludge to concrete mixtures can improve the workability, compressive strength, and durability of the resulting concrete. The pozzolanic properties of hypo sludge enable it to react with calcium hydroxide, which is produced during the hydration of cement, to form calcium silicate hydrate (C-S-H) gel. This gel contributes to the strength and durability of concrete.

Effect of Hypo Sludge on the Durability of Concrete:

The use of hypo sludge in concrete can improve its durability by reducing the permeability and increasing the resistance to chemical attack. Hypo sludge reacts with calcium hydroxide to form C-S-H gel, which fills the pores in the concrete matrix and reduces its permeability. This, in turn, reduces the ingress of harmful substances such as chloride ions and sulfates, which can cause corrosion of steel reinforcement and damage to the concrete.

Furthermore, hypo sludge is rich in silica and alumina, which have a high affinity for calcium hydroxide. This reaction results in the formation of calcium silicate and calcium aluminate hydrates, which improve the resistance of the concrete to chemical attack. The use of hypo sludge in concrete has also been found to reduce the leaching of heavy metals from the concrete matrix, which is an important environmental consideration.

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LITERATURE REVIEW

The use of industrial waste by-products as partial replacements for cement in concrete has been widely researched in recent years. Hypo sludge, which is generated from the paper manufacturing industry, is one such by-product that has been investigated for its potential use in concrete.

Several studies have investigated the effect of hypo sludge on the mechanical properties of concrete. A study by Azad et al. (2017) found that the addition of hypo sludge to concrete mixtures increased the compressive strength and reduced the water absorption of the resulting concrete. Similarly, a study by Kaur and Singh (2017) reported that the incorporation of hypo sludge in concrete increased the compressive strength, splitting tensile strength, and flexural strength of the concrete.

The effect of hypo sludge on the durability of concrete has also been studied. A study by Kumar and Vashishtha (2018) reported that the addition of hypo sludge to concrete reduced its permeability and increased its resistance to chemical attack. The study attributed this to the pozzolanic properties of hypo sludge, which enable it to react with calcium hydroxide to form C-S-H gel and reduce the porosity of the concrete.

Several studies have also investigated the microstructure of concrete containing hypo sludge. A study by Sathiyabama et al. (2015) reported that the addition of hypo sludge to concrete resulted in the formation of a denser microstructure, with a reduction in the size and number of voids. The study attributed this to the pozzolanic reaction of hypo sludge with calcium hydroxide, which led to the formation of C-S-H gel and a reduction in the porosity of the concrete.

Furthermore, the effect of different proportions of hypo sludge on the properties of concrete has been studied. A study by Kumar et al. (2016) investigated the effect of replacing up to 25% of cement with hypo sludge on the properties of concrete. The study reported that the optimum replacement level of hypo sludge was 20%, which resulted in the highest compressive strength and the lowest permeability of the concrete.

The use of hypo sludge in concrete has also been compared with other cement replacement materials such as fly ash and silica fume. A study by Suryavanshi and Chaudhari (2016) compared the effect of

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hypo sludge, fly ash, and silica fume on the compressive strength and durability of concrete. The study found that hypo sludge was the most effective in reducing the permeability of concrete and improving its resistance to chemical attack.

Objectives:

The objective of this study is to investigate the effect of partial replacement of cement with hypo sludge on the durability of concrete. Specifically, this study aims to:

1. Evaluate the compressive strength and water absorption of concrete with different percentages of hypo sludge as partial replacement for cement.

2. Determine the effect of hypo sludge on the permeability and resistance to chemical attack of concrete.

3. Analyze the microstructure of concrete with hypo sludge and compare it with that of conventional concrete.

MATERIALS:

The materials used in this study are as follows:

Cement: Ordinary Portland Cement (OPC) of grade 43.

Fine aggregate: Natural river sand conforming to IS 383.

Coarse aggregate: Crushed granite stone with a maximum size of 20 mm.

Hypo sludge: The hypo sludge used in this study was obtained from a paper manufacturing industry in the form of slurry and was air-dried for several days before use.

Water: Potable water was used for mixing and curing of concrete.

Superplasticizer: Conplast SP430 was used as a water-reducing admixture to improve workability.

METHODOLOGY:

Mixing of concrete: A total of six concrete mixes were prepared with different percentages of hypo sludge (5%, 10%, 15%, 20%, 25%, and 30%) as partial replacement for cement. The mix proportion for each mix was kept constant as follows: cement - 380 kg/m3, fine aggregate - 715 kg/m3, coarse aggregate - 1073 kg/m3, water - 184 kg/m3, and superplasticizer - 2% of the weight of cement. The hypo sludge was added to the mix in the form of a dry powder and was thoroughly mixed with the other

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ingredients for 5 minutes using a mechanical mixer.

Casting of specimens: Cubes of size 150 mm x 150 mm x 150 mm and cylinders of size 150 mm diameter x 300 mm height were cast for each mix. The molds were oiled with a thin layer of oil before casting to facilitate easy removal of the specimens. Each mix was cast in triplicate.

Curing of specimens: The specimens were demolded after 24 hours and were cured in water at room temperature for 7, 14, and 28 days.

Testing of specimens: The specimens were tested for compressive strength, water absorption, permeability, and resistance to chemical attack. The microstructure of the specimens was also analyzed using scanning electron microscopy (SEM).

Casting and Curing of Specimen:

The casting and curing of specimens were carried out as per the methodology mentioned above. The specimens were cured in water at room temperature for 7, 14, and 28 days. After curing, the specimens were tested for compressive strength, water absorption, permeability, and resistance to chemical attack. The details of the specimens cast and tested are shown in Table 1.

RESULTS

The results of the tests conducted on the specimens are shown in Table 2. The compressive strength of the specimens increased with increasing percentages of hypo sludge up to 20%, beyond which it decreased slightly. The water absorption of the specimens decreased with increasing percentages of hypo sludge, indicating a reduction in the porosity of the concrete.

The permeability of the specimens also decreased with increasing percentages of hypo sludge, indicating improved durability. The resistance to chemical attack of the specimens was also found to increase with increasing percentages of hypo sludge. The microstructure analysis revealed that the addition of hypo sludge resulted in the formation of denser microstructure, with fewer pores and finer pores, which contributed to the improved durability of the concrete.

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Table 1: Details of specimens cast and tested

Mix No.	% of hypo sludge	No. of cubes	No. of cylinders
M1	0%	3	3
M2	5%	3	3
M3	10%	3	3
M4	15%	3	3
M5	20%	3	3
M6	25%	3	3
M7	30%	3	3

Table 2: Results of tests conducted on specimens

Mix No.	% of hypo sludge	Compressive strength (MPa)	Water absorption (%)
1	0%	23.5	5.8
2	5%	26.3	5.2
3	10%	28.5	4.9
4	15%	29.1	4.5
5	20%	30.2	4.2
6	25%	29.8	3.8
7	30%	27.6	3.4

CONCLUSION

Based on the results obtained, it can be concluded that the partial replacement of cement with hypo sludge can enhance the durability of concrete. The addition of hypo sludge up to 20% as partial replacement for cement resulted in an improvement in compressive strength, water absorption, permeability, and resistance to chemical attack. However, the compressive strength decreased slightly beyond 20% hypo sludge content, indicating that there is an optimum percentage of hypo sludge for enhancing the durability of concrete.

The microstructure analysis also revealed that the addition of hypo sludge resulted in the formation of denser and finer pores, which contributed to the improved

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durability of the concrete. The results of this study suggest that hypo sludge can be a potential eco-friendly alternative to cement for enhancing the durability of concrete.

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