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EVALUATION OF STRENGTH PROPERTIES OF CONCRETE WITH ABACA FIBER, HYPOSLUDGE, AND QUARRY DUST

[1]DR.K.CHANDRAMOULI, [2] J.SREE NAGA CHAITANYA, [3]K.DIVYA, [4]PEEKE ANJAIAH

[1]Professor & HOD, [2, 3] Assistant Professor,[4]B. Tech Student
[1,2,3,4] Department of Civil Engineering, NRI Institute of Technology, Visadala (V), Medikonduru (M), Guntur, Andhra Pradesh, INDIA .
Email:jarugumillichaitanya1989@gmail.com, koduru_mouli@yahoo.com

ABSTRACT

This research explores the formulation of sustainable concrete by judiciously incorporating industrial by-products and natural fibers. It investigates the efficacy of partially replacing natural fine aggregate with quarry dust and cement with hyposludge, a paper mill waste. Furthermore, the study examines the beneficial impact of adding abaca fibers to the concrete mix. This multi-pronged approach aims to enhance mechanical properties, reduce reliance on virgin materials, mitigate environmental pollution from waste disposal, and ultimately contribute to greener construction practices. The objective is to achieve concrete with comparable or superior performance, promoting resource efficiency and a reduced carbon footprint in the construction industry. Tests were conducted for compressive strength and** split **tensile strength**at**28, 56, and 90 days to assess long-term performance.

KEYWORDS*: *Sustainable Concrete, Quarry Dust, Hyposludge, Abaca Fiber, Industrial Waste Utilization

INTRODUCTION

Concrete is a fundamental and widely used construction material, ranking second only to water in global consumption. It is a composite formed by mixing cement, aggregates such as sand and gravel, and water. Through the hydration process, the cement reacts with water to form a hardened paste that binds the aggregates into a solid, stone-like mass. Concrete's exceptional versatility, strength, and durability make it essential for modern infrastructure, providing the structural foundation for everything from skyscrapers and highways to bridges, dams, and residential buildings. Its ability to be shaped into any form when fresh, along with its resistance to heavy loads, fire, and harsh environmental conditions, underpins its extensive use worldwide.

Given this, there is an increasing need to find sustainable and cost-effective alternatives to traditional concrete components. Quarry dust, a fine byproduct produced in large quantities during stone crushing, offers a promising option. Much of this material is often discarded, causing disposal problems and environmental pollution. Using quarry dust as a partial substitute for natural fine aggregate in concrete provides a twofold advantage: it conserves natural sand resources and helps manage industrial waste effectively. Current research focuses on validating its suitability and optimizing its use to maintain or improve concrete performance.

The manufacture of cement is highly energy-demanding and contributes significantly to global carbon dioxide emissions and resource depletion. This environmental impact drives the search for greener alternatives. Hypo sludge, a major waste byproduct from the paper industry, presents considerable disposal challenges, occupying landfill space and potentially harming ecosystems. However, hypo sludge contains valuable compounds like silica and calcium, key components in cementitious materials, making it a potential supplementary cement replacement. Incorporating hypo sludge into concrete can reduce cement consumption and its environmental footprint while addressing paper mill waste disposal. This study aims to evaluate the feasibility and effectiveness of using hypo sludge as a partial cement substitute, fostering resource efficiency and supporting a circular economy in construction.

Although concrete boasts high compressive strength, it is naturally brittle with low tensile strength and limited ductility. This weakness leads to cracking under tensile stress and sudden failure under excessive loads, posing a significant challenge. The addition of fibers is a well-established approach to improve these properties, making concrete more ductile and resistant to cracking. Among fiber types, natural fibers are increasingly favored for their sustainability, renewability, and affordability. Abaca fiber, derived from the Musa textilis plant, is especially notable due to its high tensile strength, stiffness, and durability, even under harsh conditions.

2. OBJECTIVES

1. To identify the optimal percentage of quarry dust as a partial replacement for natural fine aggregate that maximizes both compressive and split tensile strength of concrete.

2. To examine the effects of partially substituting cement with varying amounts of hyposludge on the compressive and split tensile strength, aiming to find a mix that sustains or improves these mechanical properties.

3. To assess the influence of different concentrations of abaca fibers on the compressive and split tensile strength of concrete, focusing on their capacity to enhance ductility and resistance to cracking.

3. MATERIALS

3.1 Cement: Cement is a fine powder that acts as a binding agent. When mixed with water, it undergoes a chemical reaction called hydration, forming a hardened, stone-like material. Its main role in construction is to bind aggregates such as sand and gravel together, creating a strong and durable composite known as concrete.

3.2 Fineaggregate: Fine aggregate comprises small inert particles, usually natural sand or crushed stone, with sizes typically less than 4.75 mm. It fills the spaces between coarse aggregates in concrete; improving workability, density, and surface finish, while also affecting the overall strength and durability of the hardened concrete.

3.3 Coarse aggregate: Coarse aggregate consists of larger granular materials like gravel or crushed stone, generally retained on a 4.75 mm sieve. It provides the main structural framework of concrete, contributing to volume, increasing compressive strength, and reducing shrinkage during drying, thereby enhancing the concrete's integrity and durability.

3.4 Water: Water is a vital ingredient in concrete, initiating the hydration process with cement that leads to hardening and strength development. It also acts as a lubricant, improving workability to facilitate placement, compaction, and finishing. The water-to-cement ratio is critical in determining the concrete's final strength, durability, and porosity.

3.5Quarry Dust: Quarry dust is a byproduct generated during the crushing of rocks, consisting of fine, inert particles smaller than 4.75 mm. It serves as a sustainable substitute for natural sand in concrete, helping to conserve natural resources while addressing industrial waste disposal issues.

3.6 Hyposludge: Hyposludge is a waste residue from the paper manufacturing process, rich in lime and silica. Its chemical composition makes it a viable supplementary cementitious material. Incorporating hyposludge in concrete reduces cement consumption and helps mitigate environmental pollution caused by paper mill waste.

3.7 Abaca Fiber: Abaca fiber is a natural, high-strength fiber extracted from the leaf stalks of the Musa textilis plant. Known for its excellent tensile strength and durability, it acts as an effective reinforcement in brittle materials like concrete, enhancing flexural strength, toughness, and resistance to cracking.

4. EXPERIMENTAL RESULTS

4.1 Compressive strength:- Compressive strength measures a material's ability to resist forces that try to crush or compress it. This is typically determined by gradually applying load to a standardized

Table 1: Compressive strength results of concrete with different percentages of Quarry dust used as a partial replacement of fine aggregate.

Sl.no	% Of Quarry Dust	Compressive Strength Results, N/mm^2		
		28 days	56 days	90 days
1	0%	49.43	53.62	57.51
2	10%	53.41	58.17	62.35
3	20%	56.96	62.08	66.64
4	30%	59.72	65.11	69.76
5	40%	58.85	64.65	68.83

Table 2: Compressive strength results of concrete with different percentages of Hyposludge used as a partial replacement of Cement.

Sl.no	% Of Hyposludge	Compressive Strength Results, N/mm^2		
		28 days	56 days	90 days
1	0%	49.43	53.62	57.51
2	5%	57.46	62.37	67.07
3	10%	64.78	70.58	75.77
4	15%	59.21	64.62	69.42

Table 3: Compressive strength results of abaca fiber concrete.

Sl.no	% Of Abaca fiber	Compressive Strength Results, N/mm^2		
		28 days	56 days	90 days
1	0%	49.43	53.62	57.51
2	0.25%	55.45	60.24	64.51
3	0.5%	58.82	64.03	68.72
4	1%	52.36	57.12	61.22

Table 4: Compressive strength results of Combined replacement of 30% QD+10% HS+0.5% AF in concrete.

Sl.no	30% QD+10% HS+0.5% AF	Compressive Strength Results, N/mm^2		
		28 days	56 days	90 days
1	0%	49.43	53.62	57.51
2	30% QD+10% HS+0.5% AF	73.21	79.82	85.64

4.2 Split tensile strength

Split tensile strength is an indirect measure of concrete's resistance to tensile forces, given that concrete is weak in direct tension. The test involves placing a cylindrical specimen horizontally and applying a compressive load along its diameter, causing the cylinder to split due to the tensile stresses induced. This test is conducted at curing periods of 28, 56, and 90 days to evaluate cracking resistance in concrete structures.

Table 5: Split tensile strength results of concrete with different percentages of Quarry dust used as a partial replacement of fine aggregate.

Sl.no	% Of Quarry Dust	Split tensile Strength Results, N/mm^2		
		28 days	56 days	90 days
1	0%	4.81	5.24	5.67
2	10%	4.94	5.38	5.74
3	20%	5.66	6.17	6.64
4	30%	6.08	6.62	7.11
5	40%	5.72	6.23	6.68

Table 6: Split tensile strength results of concrete with different percentages of Hyposludge used as a partial replacement of Cement.

Sl.no	% Of Hyposludge	Split tensile Strength Results, N/mm^2		
		28 days	56 days	90 days
1	0%	4.81	5.24	5.67
2	5%	5.68	6.17	6.26
3	10%	6.53	7.09	7.56
4	15%	5.79	6.35	6.78

Table 7: Split tensile strength results of Abaca fiber concrete.

Sl.no	% Of Abaca fiber	Split tensile Strength Results, N/mm^2		
		28 days	56 days	90 days
1	0%	4.81	5.24	5.67
2	0.25%	5.47	5.92	6.45
3	0.5%	5.78	6.31	6.64
4	1%	5.19	5.67	6.07

Table 8: Split tensile results of combined replacement of 30% QD+10% HS+0.5% AF in concrete.

Sl.no	30% QD+10% HS+0.5% AF	Split tensile Strength Results, N/mm^2		
		28 days	56 days	90 days
1	0%	4.81	5.24	5.67
2	30% QD+10% HS+0.5% AF	7.31	7.96	8.48

5. CONCLUSION

1. **Replacing 30% of fine aggregate with Quarry Dust** resulted in the highest strength within that category, with a **28-day strength increase of 21.0%**, **56-day increase of 21.4%**, and **90-day increase of 21.3%** compared to the control mix.
2. **Using 10% Hyposludge as a partial cement replacement** gave the optimum result, with the compressive strength increasing by **31.1% at 28 days**, **31.6% at 56 days**, and **31.7% at 90 days** over the control concrete.
3. **Incorporating 0.5% Abaca fiber** into the concrete mix yielded the highest strength in that category, with improvements of **19.1% at 28 days**, **19.2% at 56 days**, and **19.5% at 90 days**, indicating this is the most effective dosage.
4. The **combined use of 30% Quarry Dust, 10% Hyposludge, and 0.5% Abaca fiber** produced the **maximum overall strength**, showing a dramatic increase of **48.1% at 28 days**, **48.9% at 56 days**, and **48.9% at 90 days** compared to the plain concrete.
5. Overall, the study shows that **optimum partial replacements** of conventional materials with sustainable alternatives significantly enhance compressive strength, with the combined mix outperforming individual replacements in every curing period.
6. **Replacing 30% of fine aggregate with Quarry Dust** resulted in the highest split tensile strength among all Quarry Dust mixes, with values increasing to **6.08 N/mm² at 28 days**, **6.62 N/mm² at 56 days**, and **7.11 N/mm² at 90 days**, reflecting improvements of up to **25.3%** over the control mix.
7. **Using 10% Hyposludge as a partial replacement for cement** provided the highest split tensile strength in that group, reaching **6.53 N/mm² at 28 days**, **7.09 N/mm² at 56 days**, and **7.56 N/mm² at 90 days**, representing an increase of up to **33.3%** compared to conventional concrete.
8. **Incorporating 0.5% Abaca fiber** yielded the optimum split tensile strength for fiber-reinforced mixes, with values of **5.78 N/mm² at 28 days**, **6.31 N/mm² at 56 days**, and **6.64 N/mm² at 90 days**, indicating a consistent enhancement of around **17–20%** across all curing periods.
9. The **combined replacement mix of 30% Quarry Dust, 10% Hyposludge, and 0.5% Abaca fiber** achieved the highest split tensile strength overall, reaching **7.31 N/mm² at 28 days**, **7.96 N/mm² at 56 days**, and **8.48 N/mm² at 90 days**, marking a substantial increase of up to **49.5%** compared to the control concrete.
10. Overall, the results confirm that combining optimized levels of Quarry Dust, Hyposludge, and Abaca fiber leads to **maximum enhancement in split tensile strength**, significantly outperforming individual replacements and demonstrating the potential for high-performance, sustainable concrete.

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