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INVESTIGATION ON HEMP FIBER CONCRETE WITH DOLOMITE AND METAKAOLIN

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ABSTRACT

This study investigates the performance of concrete incorporating hemp fibers as an additive, alongside the individual partial replacement of cement with dolomite and met kaolin. The research aims to evaluate the mechanical properties of these modified concrete mixes. Initial findings suggest that hemp fiber inclusion can enhance concrete's tensile strength and ductility. Meanwhile, dolomite and metakaolin as cement substitutes show promise in improving long-term strength and reducing environmental impact. This abstract highlights the potential for developing sustainable and high-performance concrete materials. Further analysis will delve into optimal replacement ratios and their synergistic effects. The investigation seeks to contribute to greener construction practices. Test for compressive strength and split tensile strength for 7 and 28 days.

KEYWORDS: Dolomite, Metakaolin, Hemp Fiber, Environmental impact, Compressive strength, Split tensile strength

1. INTRODUCTION

In terms of volume, concrete an artificial rock-like substance is the most often utilized building material worldwide. Cement, fine and coarse aggregates, and water make up the majority of its composition; admixtures are frequently added to change its characteristics. The hydration process, in which cement and water combine chemically to create a solid, binding paste that envelops the particles, is what gives concrete its charm. Over time, this paste becomes stronger and harder, creating a composite that is both long-lasting and adaptable. Its remarkable compressive strength, fresh moldability, and reasonable cost account for its extensive use. Concrete is the core of contemporary infrastructure, influencing the built environment globally through anything from massive bridges and tall skyscrapers to common pavements and home foundations.

Dolomite is an anhydrous carbonate mineral with the chemical formula $\text{CaMg}(\text{CO}_3)_2$. It's also the name for a sedimentary rock (dolostone) predominantly composed of this mineral. Often called dolomitic limestone, it forms when calcium carbonate (limestone) undergoes partial or full transformation through a process called dolomitization, typically involving magnesium-rich fluids. Dolomite is characterized by its hardness, durability, and a wide range of colors. It finds extensive use in construction as an aggregate, in cement production, and as a filler in various building materials. Its unique properties make it a valuable resource across many industries.

Metakaolin is a highly reactive pozzolanic material derived from the calcination of kaolin clay. This manufacturing process involves heating purified kaolinite to specific temperatures, typically between 600-800°C, which dehydroxylates the clay and transforms it into an amorphous aluminosilicate. Unlike industrial by-products, metakaolin is engineered for its performance in cementitious systems. Its finer particle size and high reactivity allow it to consume calcium hydroxide released during cement hydration, forming additional strength-contributing compounds. Metakaolin is highly valued in concrete for improving strength, durability, and resistance to chemical attack. It also contributes to reduced permeability and a lighter color in finished concrete.

Hemp fibers are increasingly explored as a sustainable reinforcement in concrete, offering a "green" alternative to conventional synthetic fibers. Derived from the *Cannabis sativa* plant, these natural lignocellulosic fibers possess good tensile strength and a relatively low density. When incorporated into concrete, hemp fibers can enhance its flexural strength and ductility, mitigating the brittle nature of traditional concrete. They also contribute to improved crack resistance by bridging micro-cracks and distributing stress more effectively. Furthermore, hemp fibers can aid in internal curing by absorbing and slowly releasing water, which is beneficial for concrete hydration. This contributes to a more sustainable and potentially higher-performing concrete composite.

2. OBJECTIVES

1. To investigate the efficacy of dolomite as a partial replacement for cement in concrete mixes, focusing on its impact on **compressive and tensile strength**.
2. To determine the impact of metakaolin as a partial cement replacement on the **early and long-term compressive strength** of concrete, leveraging its pozzolanic activity.
3. To investigate the role of hemp fibers in enhancing the **crack resistance and post-cracking behavior** of concrete.

3. MATERIALS

3.1 Cement: Cement is a finely ground binding material that, when mixed with water, hardens to bind aggregates like sand and gravel. This process creates strong, durable materials such as mortar and concrete. Made primarily from limestone, clay, and other minerals, cement is fundamental to the stability and longevity of buildings and infrastructure.

3.2 Fine aggregate: Fine aggregate, typically sand or crushed stone, consists of small particles that pass through a 4.75 mm sieve. It's crucial in both mortar and concrete for filling the voids between larger coarse aggregate particles, contributing to the mix's density and workability.

3.3 Coarse aggregate: Coarse aggregate consists of larger particles like crushed stone or gravel, which are retained on a 4.75 mm sieve. This material forms the structural backbone of concrete mixes, adding bulk, strength, and durability. It significantly enhances a structure's overall stability and its ability to bear heavy loads.

3.4 Water: Water is an indispensable component in various construction processes, including mixing cement, preparing mortar, and curing concrete. The quality of the water directly impacts the strength and lifespan of both cement concrete and mortar, thus influencing the overall performance of the finished structure.

3.5 Dolomite Powder: Dolomite powder is a fine, ground material produced from naturally occurring dolomite rock. Chemically, it's a double carbonate of calcium and magnesium, with the formula $\text{CaMg}(\text{CO}_3)_2$. It's widely used across industries, including construction, agriculture, and glass manufacturing, due to its unique chemical and physical properties.

3.6 Metakaolin: Metakaolin is a highly reactive pozzolanic material obtained by calcining kaolin clay at specific temperatures (600-800°C). This process transforms the clay into an amorphous aluminosilicate, making it a valuable supplementary cementitious material. It significantly enhances concrete's strength, durability, and resistance to chemical attack.

3.7 Hemp fiber: Hemp fiber is a natural, lignocellulosic fiber derived from the stalk of the *Cannabis sativa* plant, specifically cultivated varieties with very low THC content. They are processed through retting and decortication to separate them from the woody core, and are used in a wide range of applications, including textiles, paper, ropes, composites, and sustainable building materials like hempcrete.

4. EXPERIMENTAL RESULTS

4.1 Compressive strength

The minimum compressive strength of a cube is represented as the cube of compressive strength (15 cm x 15 cm x 15 cm). The cubes are usually assessed after 7 and 28 days.

Table 1: Compressive strength results of concrete with Dolomite Powder used as a partial replacement for cement.

Sl.no	% of Dolomite Powder	Compressive Strength Results, N/mm ²	
		7 days	28 days
1	0%	33.75	49.72
2	5%	35.84	52.11
3	10%	38.19	54.64
4	15%	40.12	56.71
5	20%	36.87	53.23
6	25%	36.19	51.78

Table 2: Compressive strength results of concrete with Metakaolin used as a partial replacement for cement.

Sl.no	% of Metakaolin	Compressive Strength Results, N/mm ²	
		7 days	28 days
1	0%	33.75	49.72
2	5%	36.93	52.81
3	10%	38.71	55.23
4	15%	39.22	57.35
5	20%	37.78	54.68

Table3: Compressive strength of Hemp fiber concrete.

Sl.no	% of Hemp fibers	Compressive Strength Results, N/mm ²	
		7 days	28 days
1	0%	33.75	49.72
2	0.25%	37.24	53.28
3	0.5%	38.46	55.93
4	0.75%	41.89	58.97
5	1%	39.92	58.33

Table4: Ccombined Compressive strength of concrete with 15%MK+15%Dol+0.75% HF.

Sl.no	Combined Replacement(s)	Compressive Strength Results, N/mm ²	
		7 days	28 days
1	0%	33.75	49.72
2	15%MK+15%Dol+0.75% HF	46.38	66.19

4.2 Split tensile strength

A load is applied along a horizontal cylindrical specimen until failure occurs to estimate the material's split tensile strength, which is a measurement of its resistance to tension. Better durability and resistance to cracking in concrete constructions for 7 and 28 days.

Table 5: Split tensile strength results of concrete with Dolomite Powder used as a partial replacement for cement.

Sl.no	% of Dolomite Powder	Split tensileStrength Results, N/mm ²	
		7 days	28 days
1	0%	3.32	4.94
2	5%	3.64	5.22
3	10%	3.78	5.41
4	15%	4.02	5.68
5	20%	3.71	5.37
6	25%	3.69	5.22

Table 6: Split tensile strength results of concrete with Metakaolin used as a partial replacement for cement.

Sl.no	% of Metakaolin	Split tensileStrength Results, N/mm ²	
		7 days	28 days
1	0%	3.32	4.94
2	5%	3.61	5.27
3	10%	3.88	5.49
4	15%	3.94	5.83
5	20%	3.71	5.38

Table7: Split tensile strength of Hemp fiber concrete.

Sl.no	% of Hemp fibers	Split tensileStrength Results, N/mm ²	
		7 days	28 days
1	0%	3.32	4.94
2	0.25%	3.73	5.32
3	0.5%	3.86	5.56
4	0.75%	4.21	5.93
5	1%	3.98	5.79

Table8: Ccombined Split tensile strength of concrete with 15%MK+15%Dol+0.75% HF.

Sl.no	Combined Replacement(s)	Split tensile Strength Results, N/mm ²	
		7 days	28 days
1	0%	3.32	4.94
2	15%MK+15%Dol+0.75% HF	4.81	6.74

5. CONCLUSION

1. The normal concrete compressive strength results for 7 days and 28 days is 33.75N/mm² and 49.72 N/mm².

2. At 15% partial replacement of cement with dolomite powder which gives compressive strength result for 7 days and 28 days is 40.12N/mm² and 56.71N/mm².
3. At 15% partial replacement of cement with metakaolin which gives compressive strength result for 7 days and 28 days is 39.22 N/mm² and 57.35N/mm².
4. At 0.75% addition of Hemp Fibre to concrete then the compressive strength result for 7 days and 28 days is 41.89N/mm² and 58.97N/mm².
5. Compressive strength result for combined replacement of 15% dolomite and metakaolin for cement and 0.75% hemp fiber is addition to concrete for 7 days and 28 days is 46.38 N/mm² and 66.19N/mm².
6. The normal concrete split tensile strength results for 7 days and 28 days is 3.32N/mm² and 4.94 N/mm².
7. At 15% partial replacement of cement with dolomite powder which gives split tensile strength result for 7 days and 28 days is 4.02 N/mm² and 5.68 N/mm².
8. At 15% partial replacement of cement with metakaolin which gives split tensile strength result for 7 days and 28 days is 3.94 N/mm² and 5.83 N/mm².
9. At 0.75% addition of Hemp Fibre to concrete then the split tensile strength result for 7 days and 28 days is 4.21 N/mm² and 5.93N/mm².
10. split tensile strength result for combined replacement of 15% dolomite and metakaolin for cement and 0.75% hemp fiber is addition to concrete for 7 days and 28 days is 4.81 N/mm² and 6.74 N/mm².

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