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Exploration of Carbon Fiber Concrete with Silica Fume Admixture for Potential Application in Rigid Pavement Systems

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ABSTRACT- Concrete is a crucial material in civil engineering construction, but its traditional components, coarse and fine aggregate, are becoming increasingly expensive and scarce. This study aimed to investigate the potential of replacing cement with silica fumes and fine aggregate with carbon fibers to improve concrete's hardened properties. Different concrete mixes were created with varying percentages of these replacements. The resulting concrete specimens were tested for compression, split, and flexural strength after curing periods of 7 and 28 days.

KEYWORDS- Fiber-reinforced Concrete, Aspect Ratio, Glass Fiber Reinforced Concrete (GFRC), Pozzolanic

I. INTRODUCTION

India's rapid infrastructure development, including buildings, highways, power plants, industrial structures, and dams, has been driven by globalization. Concrete, a key component of civil engineering projects, is in high demand [1] . However, the scarcity and rising cost of coarse and fine aggregate, essential materials for conventional concrete, have created a need for alternative materials[3] . Waste tire management is a global concern, with millions of tires discarded or burned annually, causing environmental and health problems [2]. The long-term persistence of carbon fibers in landfills poses a significant environmental hazard.

A. Fiber Reniforced Concrete

Fiber-reinforced concrete (FRC) is a type of concrete that contains short, evenly spaced fibers. These fibers can be made from various materials like steel, glass, or synthetic fibers and can significantly improve the strength and durability of the concrete [4]. The effectiveness of the fibers depends on their shape and size. FRC is often more cost-effective and stronger than traditional concrete reinforced with steel bars [6] .However, the specific type, size, and arrangement of the fibers can impact the final performance of the FRC [5]. For instance, short, thin glass fibers can improve the early strength of the concrete but may not significantly increase its overall compressive strength.

B. Effect of Fibers in Concrete

Fibers are often added to concrete to improve its durability and prevent cracking. While fibers can enhance the concrete's resistance to impact and erosion, they generally do not increase its compressive strength. Therefore, they cannot be used as a complete replacement for traditional steel reinforcement [7]. The amount of fibers added to concrete is typically between 0.1% and 3% of the total volume. The shape and size of the fibers, as well as their stiffness, can affect their effectiveness. Longer fibers can improve tensile strength and durability, but excessively long fibers can cause problems during mixing. Studies have shown that adding fibers to concrete has little impact on its resistance to abrasion [8]. However, fibers can significantly improve the concrete's impact resistance, especially when using short, fine fibers.topics of current interest.

C. Carbon Fibre

Carbon fibers are lightweight, heat-resistant, chemically durable, an can withstand damage [9] . They can be used to prevent cracking and shrinking in materials. These fibers improve structural properties like compressive strength, bending strength, flexibility, and resistance to damage [9]. Carbon fibers can also help reduce the effects of freezing and thawing, as well as shrinkage due to drying. Additionally, using carbon fibers can reduce resistance or impedance.

II. MATERIALS AND METHODS

A. Cement

Cement is a powdered material that is used to make concrete. It is made from clinker, a substance produced in a kiln, and other ingredients. When mixed with water, it forms a paste that binds together sand, gravel, and other materials to create concrete. Cement is used in construction because it hardens when exposed to water. The most common type of cement is ordinary Portland cement (OPC), which is classified based on its strength. Portland cement concrete is widely used in construction due to its low cost, versatility, and ease of maintenance. This study used Khyber 43 grade ordinary Portland cement, which was fresh and free of clumps are shown in figure 1.

Figure 1. Sample of Cement

B. Aggregates

Generally, aggregates occupy 70% to 80% of the volume of concrete and have an important influence on its properties. They are granular materials, derived for the most part from natural rock (crushed stone, or natural gravels) and sands. In addition to their use as economical filler, aggregates generally provide concrete with better dimensional stability and wear resistance. In order to obtain a good concrete quality, aggregates should be hard and strong, free of undesirable impurities, and chemically stable. Soft and porous rock can restrict strength and durability, but it can also decompose during blending, reducing workability by raising particles. Contaminants such as silt, clay, dirt, or organic materials should be avoided in aggregates. If these compounds cover the aggregate surfaces, they will separate the aggregate particles from the concrete substrate, resulting in a decrease in strength. Silt, clay, and other fine debris will raise the water content of the concrete, and organic matter may interfere with cement hydration. Graph of particle size distribution of coarse aggregate are shown in figure 2, and result of fineness modulus of coarse aggregate and fine aggregate are shown below in table 1 and table 2.

Table 1: Fineness Modulus of coarse aggregate

I.S. Sieve (mm)	Weight Retained (gm)	% Retained	Cumulated % Retained (x)	Cumulative % Passing (100- x)	Requirement as per I.S 383-1970
40 mm	0	0	0	100	100
20 mm	104	5.20	5.20	94.80	85-100
10 mm	1784	89.20	94.40	5.60	05-20
4.75 mm	74	3.70	98.10	1.90	0-05
2.36 mm	0	0	98.10	1.90	-
1.8 mm	0	0	98.10	1.90	-
0.600 mm	0	0	98.10	1.90	-
0.300mm	0	0	98.10	1.90	-
0.150 mm	0	0	98.10	1.90	-
Pan	38	1.90			

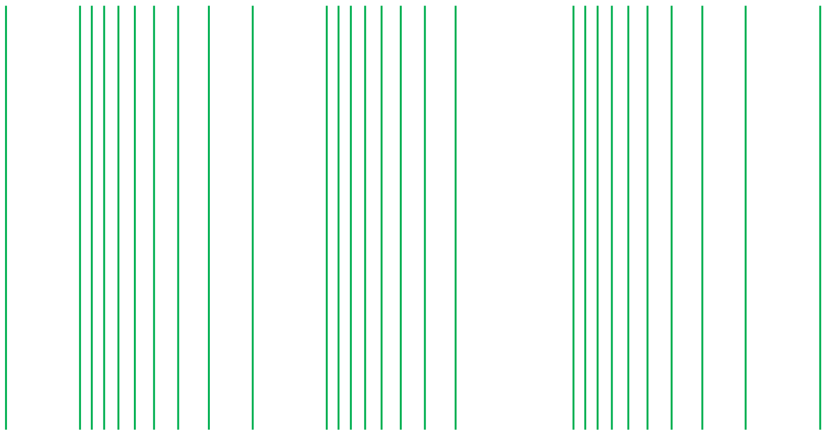

Figure 2: Graph showing particle size distribution of coarse aggregate

Table 2: Fineness modulus of fine aggregate

I.S. Sieve mm)	Weight Retained (gm)	% Retained	Cumulated % Retained (x)		Requirement as per I.S 383-1970
					ZONE II
10 mm	0	0	0	100	100
4.75 mm	28	1.87	1.87	98.13	90-100
2.36 mm	63	4.20	6.07	93.93	75-100
1.8 mm	172	11.46	17.53	82.47	55-90
0.600 mm	821	54.73	72.26	27.74	25-50
0.300mm	261	17.40	89.66	9.00	05-10
0.150 mm	109	7.27	96.93	1.07	0-5
Pan	46	1.07			

III. RESULT AND DISSCUTION

This study aimed to test how replacing cement with silica fumes and coarse aggregate with carbon fibers affects the hardened properties of concrete. Different concrete mixes were made with varying amounts of these replacements. The mixes were tested for compression, splitting, and flexural strength after curing for 7 and 28 days.

A. *Compressive Strength Test*

The results of compressive strength after 7 days of hardened concrete on replacement of cement with silica fume and fine aggregate with carbon fibers for which the percentage replacement was taken as 0%, 5%, 10%, and 20% for silica fumes and 0%, 2.5%, 5 % and 7.5% for carbon fibres. Compressive Strength after 7 days: The cube cylindrical and beam of size 15x15x15 or 10x10x10 were prepared for testing after the recommended curing time of curing period of 7 days. The results of compressive strength after 28 days are shown in table 3 and graph of compressive strength after 7 days are shown in figure 3.

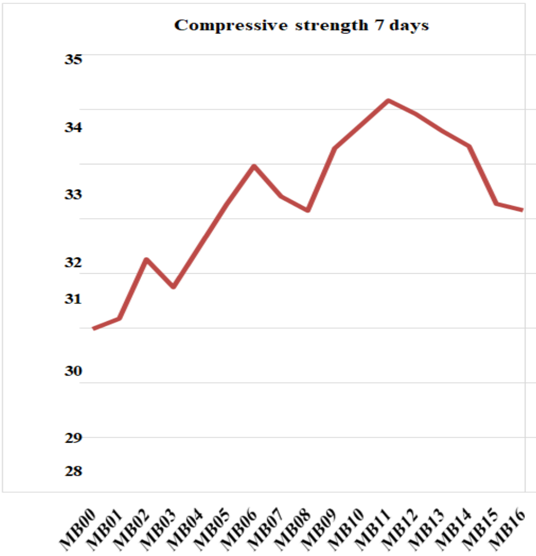

Figure 3: Compressive strength after 7 days

Table 3: Compressive strength after 28 days

Mix	Percentage of cement	Percentage of silica fume	Percentage of fine aggregate	Percentage of carbon fibber	Percentage of coarse aggregate	Compressive strength after 28 days (N/mm^2)
MB00	100	0	100	0	100	42.21
MB01	95	5	100	0	100	43.13
MB02	90	10	100	0	100	43.56
MB03	85	15	100	0	100	44.15
MB04	80	20	100	0	100	43.98
MB05	95	5	97.5	2.5	100	44.24
MB06	90	10	97.5	2.5	100	44.61
MB07	85	15	97.5	2.5	100	45.19
MB08	80	20	97.5	2.5	100	44.83
MB09	95	5	95.0	5	100	45.89
MB10	90	10	95.0	5	100	46.15
MB11	85	15	95.0	5	100	47.30
MB12	80	20	95.0	5	100	46.81
MB13	95	5	92.5	7.5	100	45.91
MB14	90	10	92.5	7.5	100	45.09
MB15	85	15	92.5	7.5	100	44.88
MB16	80	20	92.5	7.5	100	44.36

IV. CONCLUSION

This study examined how replacing cement with silica fumes and fine aggregate with carbon fibers affects concrete's strength. Different concrete mixes were made with varying amounts of these replacements and tested for compression, splitting, and flexural strength after 7 and 28 days.The results show that the strongest concrete mix overall was MB11, which contained 85% cement, 15% silica fumes, 95% fine aggregate, and 100% coarse aggregate. This mix achieved the highest compressive and flexural strength at both 7 and 28 days. Specifically:

A. Compressive strength: MB11 achieved 34.16 N/mm² at 7 days and 47.30 N/mm² at 28 days.

B. Split tensile strength: MB10 (90% cement, 10% silica fumes, 5% fine aggregate, 100% coarse aggregate) achieved 3.92 N/mm² at 7 days and 5.61 N/mm² at 28 days.

C. Flexural strength: MB11 achieved 6.40 N/mm² at 7 days and 7.85 N/mm² at 28 days.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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