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EXPERIMENTAL STUDY ON CONCRETE WITH STEEL PELLETS AND METAKAOLIN

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ABSTRACT

This study explores the influence of incorporating steel pellets and metakaolin on the strength properties of concrete. Concrete, a composite material made of cement, water, fine aggregate, and coarse aggregate, can have its performance enhanced through the addition of these materials. Steel pellets, small spherical particles typically produced from recycled steel, serve as an eco-friendly additive. Within concrete, they act as fillers that increase compressive strength and resistance to stresses. Their inclusion helps reduce cracking, improve abrasion and impact resistance, and enhance performance under freeze–thaw cycles. Steel pellets also contribute to greater fire resistance and ductility, making concrete structures stronger and more durable. Metakaolin, a pozzolanic material obtained by calcining kaolin clay, is widely used as a supplementary cementitious material. In concrete, it reacts with calcium hydroxide in the cement paste to generate additional calcium silicate hydrate (C–S–H), which improves strength, durability, and impermeability. Together, steel pellets and metakaolin provide a synergistic effect that enhances mechanical performance, increases durability, and promotes sustainability in concrete construction.

***KEYWORDS*: Metakaolin, Steel pellets,calcium silicate,durability,Compressive strength and Split tensile strength**

1. INTRODUCTION

Concrete is one of the most widely used construction materials, valued for its versatility, high compressive strength, and durability. It is a composite material consisting of cement, water, fine aggregate, and coarse aggregate, which, when properly mixed and cured, form a strong load-bearing structure. To further enhance its mechanical properties and sustainability, supplementary materials and additives are often introduced. Metakaolin, a pozzolanic material produced by calcining kaolin clay, is commonly used as a partial replacement for cement. Through its reaction with calcium hydroxide in the cement paste, it generates additional calcium silicate hydrate (C–S–H), thereby improving the strength, durability, and impermeability of concrete. Steel pellets, small spherical particles typically manufactured from recycled steel, serve as effective fillers in concrete mixtures. Their inclusion enhances compressive strength, minimizes cracking, improves resistance to abrasion and impact, and increases both ductility and fire resistance. The combined use of metakaolin and steel pellets offers a sustainable strategy for producing high-strength, durable, and long-lasting concrete, making it well-suited for demanding structural applications.

2. OBJECTIVES

1. To examine the effects of incorporating steel pellets and metakaolin on the compressive strength and split tensile strength of concrete at 28, 56 and 90 days of curing.
2. To identify the optimal proportion of steel pellets and metakaolin that maximizes the mechanical performance and durability of concrete in comparison with conventional mixes.

3. MATERIALS

3.1 Cement: A fine powder derived from limestone and clay that functions as a binder in concrete. Upon hydration, it hardens to provide strength and stability to the mixture.

3.2 Fine Aggregate: Small granular materials such as sand, used to fill voids between coarse aggregates. They enhance the workability, cohesion, and overall consistency of the concrete mix.

3.3 Coarse Aggregate: Larger particles, typically gravel or crushed stone, incorporated to provide bulk, strength, and structural stability to concrete.

3.4 Water: An essential component of concrete, required for the hydration of cement. It ensures proper workability, setting, and strength development. Both the quality and quantity of water significantly influence the final performance of concrete.

3.5 Metakaolin: A pozzolanic material obtained by calcining kaolin clay. It reacts with the hydration products of cement to form additional binding compounds, thereby improving strength, durability, and impermeability.

3.6 Steel Pellets: Small, spherical particles made from steel, used as fillers in concrete to enhance compressive and split tensile strength, improve crack resistance, and increase durability.

4. EXPERIMENTAL RESULTS

4.1 Compressive strength: -In this test, concrete cubes of standard size (usually 150 mm × 150 mm × 150 mm) are cast and cured. After28, 56 and 90 days, the cubes are placed in a compression testing machine. Load is applied gradually until failure, and the maximum load is used to calculate compressive strength.

Table 1: Compressive strength results of concrete Metakaolin as partial replacement of cement.

Sl.no	% of Metakaolin	Compressive Strength Results, N/mm^2		
		28 days	56 days	90 days
1	0%	32.54	35.12	37.75
2	5%	34.28	37.06	39.74
3	10%	35.99	38.82	41.85
4	15%	48.72	52.61	56.59
5	20%	35.56	38.43	41.26

Table 2: Compressive strength results of concrete steel pellets as partial replacement of coarse aggregate.

Sl.no	% of Steel pellets	Compressive Strength Results, N/mm^2		
		28 days	56 days	90 days
1	0%	32.54	35.12	37.75
2	5%	44.19	47.73	51.27
3	10%	45.65	49.38	52.92
4	15%	42.31	45.69	49.04

Table 3: Compressive strength results of combined replacement of 15 % MK+10%SP in concrete.

Sl.no	15 % MK+10%SP	Compressive Strength Results, N/mm^2		
		28 days	56 days	90 days
1	0%	32.54	35.12	37.75
2	15 % MK+10%SP	48.08	51.95	55.89

4.2 Split tensile strength: - **Split tensile strength** is an indirect method to evaluate the tensile resistance of concrete, since concrete is inherently weak in direct tension. In this test, a cylindrical specimen is placed horizontally and a compressive load is applied along its diameter. This loading induces tensile stresses inside the cylinder, causing it to split along the loaded diameter. The test is carried out at 28, 56 and 90 days of curing to study the cracking behavior and tensile strength development of concrete.

Table 4: Split tensile strength results of concrete Metakaolin as partial replacement of cement.

Sl.no	% of Metakaolin	Split tensile Strength Results, N/mm^2		
		28 days	56 days	90 days
1	0%	3.21	3.46	3.73
2	5%	3.36	3.62	3.89
3	10%	3.63	3.94	4.21
4	15%	4.86	5.28	5.62
5	20%	3.49	3.73	4.04

Table 5: Split tensile strength results of concrete steel pellets as partial replacement of coarse aggregate.

Sl.no	% of Steel pellets	Split tensile Strength Results, N/mm^2		
		28 days	56 days	90 days
1	0%	3.21	3.46	3.73
2	5%	4.04	4.35	4.68
3	10%	4.56	4.92	5.24
4	15%	4.19	4.57	4.86

Table 6: Split tensile strength results of combined replacement of 15 % MK+10%SP in concrete.

Sl.no	15 % MK+10%SP	Split tensile Strength Results, N/mm^2		
		28 days	56 days	90 days
1	0%	3.21	3.46	3.73
2	15 % MK+10%SP	5.04	5.52	5.89

5. CONCLUSION

1. The **Normal concrete** without any replacement achieved a compressive strength of **32.54, 35.12 and 37.75 N/mm² at 28, 56 and 90 days.**
2. The use of **Metakaolin (MK)** as a partial replacement of cement showed optimum compressive strength at **15% replacement**, reaching and **48.72, 52.61 and56.59 N/mm² at 28, 56 and 90 days.**
3. The use of **steel pellets (SP)** as a partial replacement of coarse aggregate yielded the highest compressive strength at **10% replacement**, achieving **45.65, 49.38 and 52.92 N/mm² at 28, 56 and 90 days.**
4. The **combined replacement of15% MK + 10% SP** resulted in the maximum compressive strength, reaching **48.08, 51.95 and 55.89 N/mm² at 28, 56 and 90 days**, significantly higher than normal concrete.
5. The Normal concrete without any replacement achieved a **split tensile strength of 3.21, 3.46 and 3.73 N/mm² at 28, 56 and 90 days.**

6. The **Metakaolin (MK)** as partial replacement of cement showed optimum split tensile strength at **15% replacement,** reaching **4.86, 5.28 and 5.62 N/mm² at 28, 56 and 90 days.**
7. The **Steel pellets (SP)** as partial replacement of coarse aggregate showed the highest split tensile strength at **10% replacement,** achieving **4.56, 4.92 and 5.24 N/mm² at 28 days.**
8. The **combined replacement of 15% MK + 10% SP** gave the highest split tensile strength, reaching **5.04, 5.52 and 5.89 N/mm² at 28, 56 and 90 days**, which is significantly higher than normal concrete.

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