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Performance Evaluation of M20 Concrete Incorporating Iron Cutter Blade Dust as Partial Fine Aggregate Replacement

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ABSTRACT: The increasing demand for natural river sand and the growing accumulation of industrial metallic waste have created significant environmental and sustainability challenges worldwide. Iron cutter blade dust (ICBD), generated during machining and fabrication operations, is often disposed of as industrial waste despite possessing characteristics suitable for utilization in concrete production. This research investigates the feasibility of employing ICBD as a partial replacement for fine aggregate in M20 grade concrete. Concrete specimens were prepared with 0%, 10%, 15%, 20%, and 25% replacement of natural sand by ICBD. Compressive strength tests were conducted at curing ages of 7, 14, 21, and 28 days. Experimental results demonstrated a progressive increase in compressive strength up to a replacement level of 15%, beyond which strength gradually decreased. The maximum 28-day compressive strength achieved was 28.53 MPa at 15% replacement compared with 26.97 MPa for conventional concrete, representing an increase of approximately 5.7%. The improvement is attributed to enhanced particle packing, micro-filler action, and densification of the interfacial transition zone. The study concludes that iron cutter blade dust can serve as an effective sustainable alternative to natural fine aggregate while simultaneously reducing industrial waste disposal issues.

KEYWORDS: Iron Cutter Blade Dust, Sustainable Concrete, Fine Aggregate Replacement, Compressive Strength, Waste Utilization, Green Construction.

I. INTRODUCTION

Concrete is the most widely utilized construction material due to its versatility, durability, and economic feasibility. Fine aggregate constitutes a major component of concrete and plays a crucial role in determining its strength and workability. However, rapid urbanization and infrastructure development have significantly increased the demand for natural river sand, leading to environmental degradation, riverbank erosion, ecological imbalance, and depletion of natural resources.

Simultaneously, fabrication industries generate substantial quantities of iron cutter blade dust during cutting, grinding, and machining processes. The disposal of this metallic waste presents environmental concerns and occupies valuable landfill space. Therefore, identifying sustainable applications for such industrial by-products is essential for promoting circular economy principles within the construction industry.

The utilization of industrial waste materials in concrete has gained significant attention in recent years. Materials such as fly ash, silica fume, quarry dust, steel slag, and iron filings have demonstrated promising performance when incorporated into cementitious composites. Nevertheless, limited research has focused specifically on the utilization of iron cutter blade dust as a partial replacement for fine aggregate.

This investigation aims to evaluate the mechanical performance of concrete incorporating iron cutter blade dust and determine the optimum replacement percentage for achieving maximum strength while ensuring sustainability.

II. LITERATURE SURVEY

The concept of image inpainting was first introduced by Bertamio et al. [1]. The method was inspired by the real inpainting process of artists. The image smoothness information interpolated by the image Laplacian is propagated along the isophotes directions, which are estimated by the gradient of image rotated by 90 degrees. Exemplar Based method proposed by Criminisi et al. [2] used a best exemplar patch to propagate target patch including missing pixels. This technique uses an approach which combine structure propagation with texture synthesis and hence produced very good results. In [3], the authors decompose the image into sum of two functions and then reconstruct each function separately with structure and texture filling-in algorithms. Morphological technique is used to extract text from the images presented in [4]. In [5], the inpainting technique is combined with the techniques of finding text in images and a simple algorithm that links them. The technique is insensitive to noise, skew and text orientation. The authors in [6] have applied the CCL (connected component labelling) to detect the text and fast marching algorithm is used for Inpainting.

The work in this paper is divided in two stages. 1) Text- Detection 2) Inpainting. Text detection is done by applying morphological open-close and close-open filters and combines the images. Thereafter, gradient is applied to detect the edges followed by thresholding and morphological dilation, erosion operation. Then, connected component labelling is performed to label each object separately. Finally, the set of selection criteria is applied to filter out non text regions. After text detection, text inpainting is accomplished by using exemplar based Inpainting algorithm.

III. METHODOLOGY

Numerous researchers have explored the use of industrial waste materials in concrete production. Ismail and Al-Hashmi reported significant improvements in compressive strength through the incorporation of iron waste in concrete mixtures. Alzaed observed enhanced mechanical properties with controlled replacement levels of iron filings. Miah et al. demonstrated that metallic waste materials can effectively improve density and compressive strength through filler effects and enhanced particle packing.

Previous studies indicate that optimum replacement levels generally range between 10% and 20%, beyond which excessive metallic particles may adversely affect workability and bonding characteristics.

The existing literature highlights the potential of metallic waste utilization; however, research concerning iron cutter blade dust generated by local fabrication workshops remains limited. This study addresses this gap.

IV. EXPERIMENTAL RESULTS

Compressive Strength Profile

The 28-day compressive strength tests demonstrated a parabolic trend, showcasing an initial enhancement phase followed by degradation at higher replacement volumes.

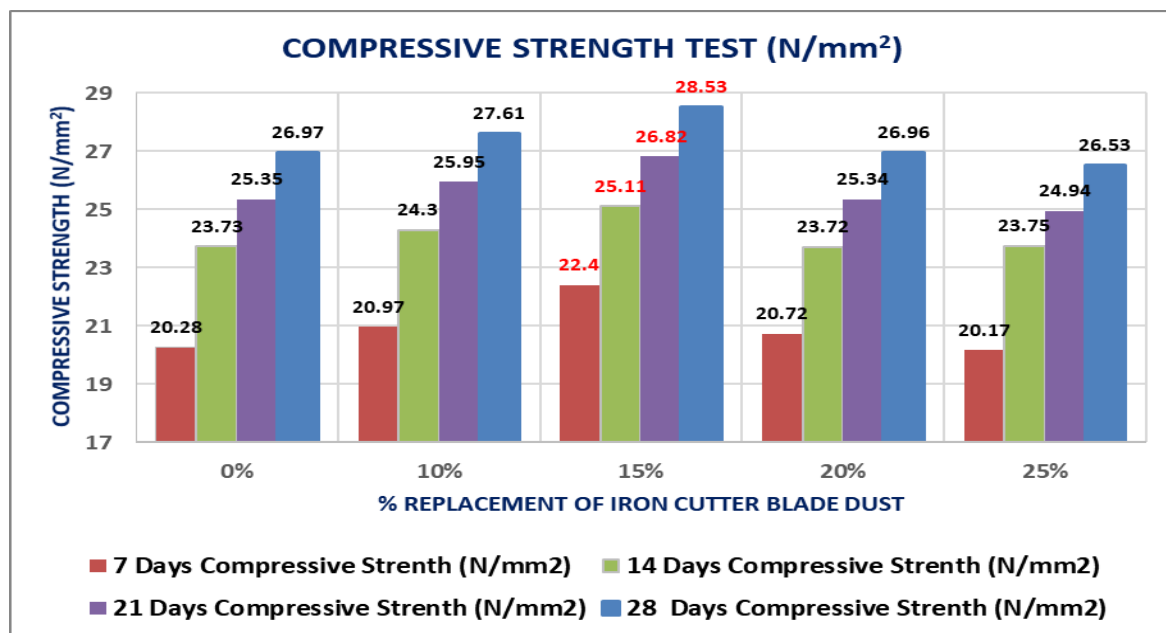
1. Baseline (0% Replacement): The standard control mix achieved an average 28-day compressive strength of 26.97 MPa.
2. Optimum Strength (15% Replacement): The 15% replacement level yielded the highest peak strength of 28.53 MPa, marking a 5.7% improvement over the control mix.
3. Degradation Phase (20% to 25% Replacement): At the 25% replacement level, compressive strength declined to 26.53 MPa, falling below the baseline control mix.

Mechanisms of Enhancement and Degradation

1. Reasons for Enhancement (up to 15%): The fine metallic particles act as highly effective micro-fillers, occupying capillary voids. This leads to the densification of the Interfacial Transition Zone (ITZ) and overall pore structure refinement, which improves stress transfer.
2. Reasons for Degradation (>15%): Because iron dust is inert, high volumes interrupt the continuity of the cement paste and disrupt chemical bonding. Furthermore, the high specific surface area of the fine dust absorbs free water, leading to a harsher mix, particle agglomeration, and the formation of macroscopic air voids.
3. Workability Impacts: Workability decreased at higher replacement levels due to the angularity and density of the metallic particles, making standard compaction less effective.

S.No.	% Replacement	Average Compressive Strength			
		7 day	14 day	21 day	28 day
1	0	20.28	23.73	25.35	26.97
2	10	20.97	24.3	25.95	27.61
3	15	22.4	25.11	26.82	28.53
4	20	20.72	23.72	25.34	26.96
5	25	20.17	23.75	24.94	26.53

Compressive Strength at 7,14,21 and 28 Days



V. CONCLUSION

Iron cutter blade dust can successfully replace natural sand in concrete. The optimum replacement level is 15%. The maximum 28-day compressive strength achieved was 28.53 MPa. Strength improvement of approximately 5.79% was observed. Sustainable utilization of industrial waste reduces environmental burden. Iron cutter blade dust has significant potential for practical implementation in concrete production.

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