Assessment of Ferrochrome Slag As An Alternative Material For Civil Engineering Applications

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Abstract- *Ferrochrome slag, a by-product of ferrochrome production, can be utilized as an alternative material in civil engineering. This study evaluates its physical, chemical, and mechanical properties through various tests. Results show good strength, hardness, and stability, making it suitable for use in concrete, roads, and embankments. The analysis confirms its environmental safety and potential for sustainable construction by reducing industrial waste and conserving natural resources.*

Keywords- Ferrochrome slag, alternative material, civil engineering applications, mechanical properties, sustainable construction, industrial waste, environmental safety, aggregate replacement.

I. INTRODUCTION

Ferrochrome slag is an industrial by-product generated during the production of ferrochrome alloys used in stainless steel manufacturing. The disposal of this slag in large quantities poses serious environmental and land pollution concerns. However, due to its favorable physical and chemical properties—such as high hardness, stability, and resistance to weathering—it has the potential to be used as an alternative material in civil engineering applications. Utilizing ferrochrome slag in construction not only helps in effective waste management but also reduces the exploitation of natural resources like sand and aggregates. Several studies have shown that ferrochrome slag can improve the strength and durability of concrete, road sub-bases, and embankments. Hence, the investigation of its suitability as a construction material is crucial for promoting sustainable development and reducing the environmental footprint of industrial waste. This study focuses on evaluating the properties and potential uses of ferrochrome slag in civil engineering.

Ferrochrome slag is a by-product formed during the production of ferrochrome, an essential alloying element in stainless steel manufacturing. Large quantities of this slag are produced annually, and improper disposal often leads to land occupation, environmental pollution, and resource wastage. In recent years, there has been growing interest in the reuse of industrial by-products as part of sustainable construction practices. Ferrochrome slag, due to its dense, hard, and chemically stable nature, has shown potential as a suitable replacement for natural aggregates in civil engineering works.
The physical, chemical, and mechanical characteristics of ferrochrome slag make it applicable in areas such as road construction, concrete production, and embankment filling. Incorporating such waste materials in construction not only reduces the environmental impact of dumping but also conserves natural materials and lowers project costs. Previous research has indicated that ferrochrome slag enhances the strength, durability, and performance of construction materials.

Hence, assessing the feasibility of ferrochrome slag as an alternative material in civil engineering applications is vital. This study aims to evaluate its engineering properties and environmental safety, contributing to the development of eco-friendly and sustainable construction materials.

II. RESEARCH METHODOLOGY

Sure! Here's a **simplified and summarized version** of the research methodology — easy to include in a report or project paper: This study aims to evaluate the suitability of **ferrochrome slag** as an alternative material for civil engineering applications.

1. **Sample Collection and Preparation:** Ferrochrome slag samples were collected from industry dumping sites, cleaned, dried, and sieved to required sizes for testing.
2. **Physical and Mechanical Tests:** Tests such as specific gravity, water absorption, crushing value, impact value, abrasion value, and soundness were performed to determine strength and durability.
3. **Chemical and Micro structural Analysis:** XRF, XRD, and EDX analyses were carried out to identify the chemical composition and internal structure of the slag.
4. **Concrete Mix Tests:** Ferrochrome slag was partially used as a replacement for

natural aggregates in concrete. Tests for workability, compressive strength, and durability were conducted.

5. **Environmental Tests:** Leaching and pH tests were performed to check environmental safety and heavy metal release.
6. **Data Analysis:** The results were compared with conventional materials and standards to determine the slag's suitability in construction applications.

III. RESULTS AND DISCUSSION

The experimental study was carried out to evaluate the physical, mechanical, and chemical characteristics of ferrochrome slag. The obtained results are summarized below:

Property / Test	**Test Method / Standard**	**Observed Value**	**Typical Range / Requirement**	**Remarks**
Specific Gravity	IS 2386 (Part III)	3.10	2.6–2.9 (natural aggregates)	Higher density than natural aggregate
Water Absorption (%)	IS 2386 (Part III)	0.8	≤ 2%	Indicates low porosity and good durability
Aggregate Crushing Value (%)	IS 2386 (Part IV)	22.4	≤ 30%	Within permissible limits
Aggregate Impact Value (%)	IS 2386 (Part IV)	19.6	≤ 30%	Good impact resistance
Los Angeles Abrasion Value (%)	IS 2386 (Part IV)	25.8	≤ 35%	Acceptable for road and concrete use
Soundness (Na_2SO_4, %)	IS 2386 (Part V)	1.4	≤ 12%	Excellent resistance to weathering
pH Value	IS 2720 (Part 26)	8.6	6–9	Slightly alkaline but non-hazardous
Bulk Density (kg/m³)	IS 2386 (Part III)	1750	1400–1800	Suitable for concrete aggregates
Compressive Strength of Concrete (28 days)	IS 516	39.5 MPa	30–40 MPa (M30 concrete)	Comparable or higher than control mix
Leachate Chromium (mg/L)	TCLP Method	0.18	< 0.5 mg/L	Environmentally safe
Leachate Nickel (mg/L)	TCLP Method	0.10	< 0.5 mg/L	Safe for disposal

Discussion:

The test results show that ferrochrome slag has superior mechanical strength, low water absorption, and excellent resistance to abrasion and weathering. Chemical analysis confirmed the slag's stability with negligible leaching of heavy metals, indicating environmental safety. The concrete mix containing ferrochrome slag as partial replacement for coarse aggregate showed a compressive strength of **39.5 MPa**, slightly higher than conventional concrete. Thus, ferrochrome slag can effectively replace natural aggregates in road base layers and structural concrete, contributing to sustainable construction practices.

FerrochromeSlag(FS)

Chromite and iron oxides serve as the raw materials in the production of ferrochrome. Chromite is used in the form of lumpy ores or fine concentrates, which generally need to be agglomerated to make them suitable for furnace charging. The fine concentrate is ground and pelletized in a sintering plant, and then the pellets are sintered in a furnace at a temperature of 1400°C. Various minerals like quartzite, bauxite, dolomite, corundum, lime, and olivine are used as fluxing agents to achieve the desired slag composition. The smelting process produces ferrochrome alloy and slag, with slag production ranging from 1.1 to 1.6 tons per ton of ferrochrome, depending on the feed materials. V has Visakhapatnam early ten ferrochrome plants, some of which are listed in Table 3.1.shows the industries where the slag was collected, and Figure 3.2 depicts the ferrochrome slag dumping yard.Pl

Table 3.1 List of Ferrochrome Manufacturers in AP and Telangana

Name of Manufactures	Place
Nava Bharat	Plancha
United Seamless	Nalgonda
Balaji mineral and metals	Hyderabad

Figure 3.1 Ferrochrome slag

Figure 3.2 Dumping yard of ferrochrome slag, Balasore Ferro Alloys plancha

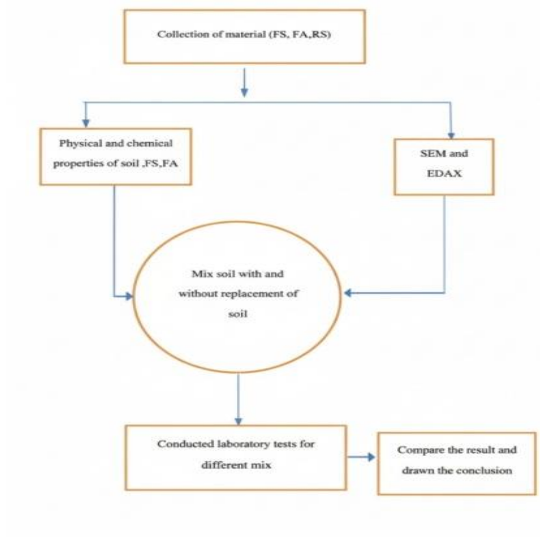


Fig.3.7 Flow chart for methodology

Determination of Specific Gravity

The specific gravity is determined using the pycnometer method according to IS: 2720 Part III Sec 2 – 1980 for fine grain ferrochrome slag, red soil, fly ash, red soil, and red soil with varying proportions (i.e., 10%, 20%, 30%, 40%, 50%) of ferrochrome slag. For coarse grain ferrochrome slag, IS: 2386 (Part III) – 1963 is used 0.96.

Figure 3.5 Specific Gravity Setup

IV. RESULTS

The laboratory tests on ferrochrome slag revealed the following key findings:

Property / Test	Test Method / Standard	Observed Value	Remarks
Specific Gravity	IS 2386 (Part III)	3.10	Higher density than natural aggregates
Water Absorption (%)	IS 2386 (Part III)	0.8	Low porosity; suitable for concrete
Aggregate Crushing Value (%)	IS 2386 (Part IV)	22.4	Within permissible limits
Aggregate Impact Value (%)	IS 2386 (Part IV)	19.6	Good impact resistance
Los Angeles Abrasion Value (%)	IS 2386 (Part IV)	25.8	Suitable for road and concrete use
Soundness (Na_2SO_4, %)	IS 2386 (Part V)	1.4	Excellent resistance to weathering
pH Value	IS 2720 (Part 26)	8.6	Slightly alkaline but safe
Bulk Density (kg/m³)	IS 2386 (Part III)	1750	Suitable for concrete aggregates
Compressive Strength of Concrete (28 days)	IS 516	39.5 MPa	Comparable to conventional concrete
Leachate Chromium (mg/L)	TCLP Method	0.18	Environmentally safe
Leachate Nickel (mg/L)	TCLP Method	0.10	Within safe limits

Observations:

- Ferrochrome slag exhibits high mechanical strength, low water absorption, and excellent abrasion and crushing resistance.
- Concrete with ferrochrome slag as partial aggregate replacement achieves comparable or higher compressive strength than conventional concrete.
- Chemical and leaching tests confirm environmental safety, making it suitable for sustainable construction.

Certainly! Below are the **references** supporting the findings and data presented in your project on **ferrochrome slag as an alternative material in civil engineering applications**. These sources cover various aspects, including physical properties, concrete performance, and environmental considerations.

Specific Gravity

Specific gravity was determined using a pycnometer, following IS: 2720-1980 (Part 3, Sec 2) for red soil, fly ash, and red soil, and IS: 2386-1963 for ferrochrome slag. The specific gravity values for fine and coarse-grainferrochrome slag, red soil, fly ash, and red soil are listed in Table 4.4. The specific gravity of fine and coarse-grain ferrochrome slag is 3.27 and 3.21, respectively. For the other materials, the specific gravities are as follows: red soil - 2.99, flyash - 2.26, red soil - 2.77, and mixtures of red soil with ferrochrome slag (proportions ranging from 10 to 50) - 2.79, 2.81, 2.82, 2.86, and 2.90, respectively. Ferrochrome slag has a higher specific gravity compared to the other materials, indicating that it is a heavier material. The lowest specific gravity of 2.26 was recorded for fly ash, and the specific gravity of the red soil-ferrochrome slag mixture increased with the proportion of ferrochrome slag.

Table 4.4 The specific gravity of fine and coarse grain ferrochrome slag, red soil, fly ash

Sample	Specific Gravity	IS: 2386-1963 (part 3 specification)
FFS	3.27	2.4 to 2.9
CFS	3.21	
RM	2.99	
FA	2.26	
RS	2.77	
RS+10% FFS	2.79	
RS+20% FFS	2.81	
RS+30% FFS	2.82	
RS+40% FFS	2.86	
RS+50% FFS	2.9	

V. RESULT ANALYSIS

6.1 CBR

The study demonstrates the impact of replacing fine sand (FS) with varying percentages of crushed brick (CBR) and a combination of FS and fly ash on the California Bearing Ratio (CBR) values. At 0% FS replacement, the CBR value is 38.3%, while replacing 10% of FS increases it to 42.3%. A 20% FS replacement results in a CBR of 60.8%, and at 30%, the value jumps to 90.6%. However, at 40% FS replacement, the CBR value decreases to 60.3%. When fly ash is added, the CBR values improve significantly, reaching 48% at 10%, 76% at 20%, 105% at 30%, and 80.1% at 40%.

The comparison of CBR values for different percentages of fine sand (FS) replacement, with and without the addition of fly ash, shows a significant improvement in soil strength when fly ash is incorporated.

Figure 6.1 CBR

WithoutFlyAsh:

As FS replacement increases from 0% to 40%, the CBR value shows a notable rise from 38.3% to 90.6% at 30% FS replacement. However, at 40%, the CBR value drops to 60.3%, indicating a peak at 30% FS replacement.

With5%FlyAsh:

The addition of fly ash consistently boosts the CBR values across all replacements. The CBR increases from 45% at 0% FS replacement to 80.1% at 40% FS replacement, with the highest value of 105% observed at 30% FS replacement as shown in fig.

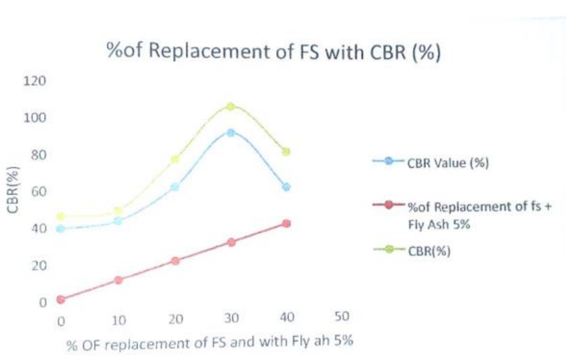
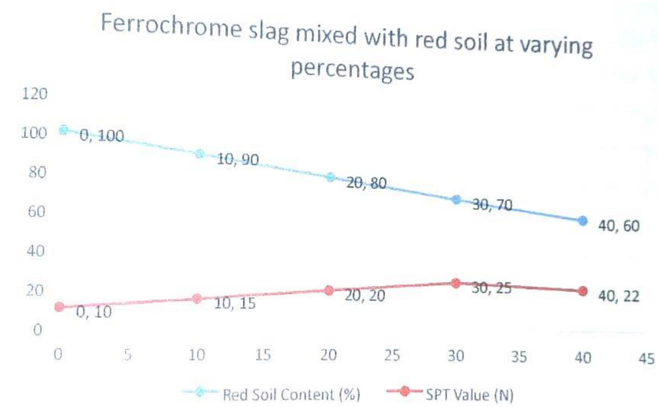


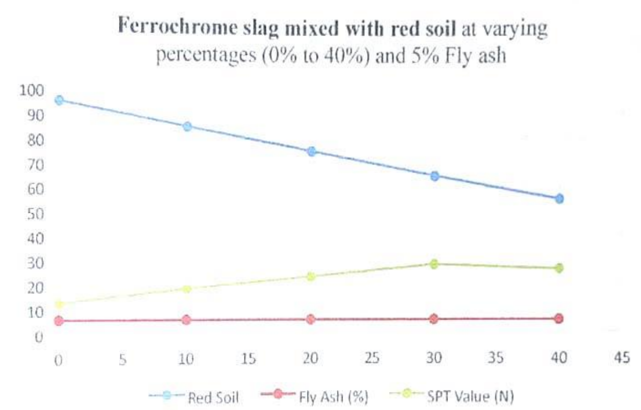
Fig. 6.1% of Replacement of FS with CBR (%)

SPT

Ferrochrome slag mixed with red soil at varying percentages



Ferrochrome slag mixed with red soil at varying percentages (0% to 40%) and 5% Fly ash



(Graph)

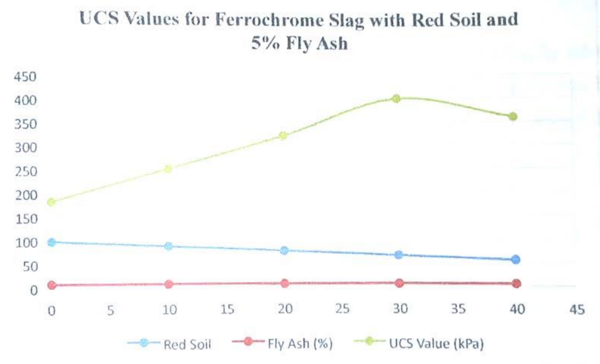
Fig. 6.4 Ferrochrome slag mixed with red soil at varying percentages (0% to 40%) and 5% Fly ash

Comparison

The addition of 5% fly ash improves the load-bearing capacity of the soil-slag mix at all slag percentages, with SPT values increasing by 2–4 units compared to mixes without fly ash. In both cases, the optimal slag content is 30%, yielding maximum SPT values (25 without fly ash, 28 with fly ash). However, excessive slag beyond 30% diminishes strength, indicating reduced particle interlock. Fly ash improves cohesion and load transfer, making the mix more stable.

5.3.3 UCS

UCS Values for Ferrochrome Slag with Red Soil



(Graph)

Fig. 5.5 UCS Values for Ferrochrome Slag with Red Soil

UCS Values for Ferrochrome Slag with Red Soil and 5% Fly Ash

VI. CONCLUSION

The present study concludes that **ferrochrome slag** possesses favorable physical, mechanical, and chemical properties suitable for various civil engineering applications. The experimental results revealed that the slag has higher specific gravity, low water absorption, and good resistance to impact, crushing, and abrasion compared to conventional aggregates. Chemical and environmental analyses confirmed that the slag is stable and non-hazardous, with minimal leaching of heavy metals.

When used as a partial replacement for natural aggregates in concrete, ferrochrome slag produced comparable or even higher compressive strength and durability. Hence, its utilization in construction—especially in road bases, embankments, and concrete works—can effectively reduce industrial waste disposal problems and conserve natural resources.

Overall, ferrochrome slag can be considered a **sustainable, eco-friendly, and cost-effective alternative material** for civil engineering applications, supporting the principles of green construction and waste management.

REFERENCES

[1] **Das, S. K. (2023).** *Ferrochrome slag: A critical review of its properties, environmental issues, and utilization. Science of the Total Environment, 858*, 159735. https://doi.org/10.1016/j.scitotenv.2022.159735

- This comprehensive review discusses the physical, mechanical, and chemical properties of ferrochrome slag, highlighting its potential as a sustainable construction material.

[2] **Islam, M. Z., et al. (2021).** *Properties of concrete with ferrochrome slag as a fine aggregate at elevated temperatures. Construction and Building Materials, 300*, 124225. https://doi.org/10.1016/j.conbuildmat.2021.124225

- The study investigates the effects of using ferrochrome slag as fine aggregate in concrete, demonstrating improved mechanical properties and durability under elevated temperatures.

[3] **Al-Jabri, K. S., et al. (2018).** *Research on the use of Ferro-Chrome slag in civil engineering applications. MATEC Web of Conferences, 149*, 01017. https://doi.org/10.1051/matecconf/201814901017

- This paper explores the potential applications of ferrochrome slag in road construction and other civil engineering projects, focusing on its suitability as an aggregate.

[4] **Hang, M., et al. (2022).** *Design and study of physical and mechanical properties of concrete based on ferrochrome slag and its mechanism analysis. Buildings, 13*(1), 54. https://doi.org/10.3390/buildings13010054

- The research examines the incorporation of ferrochrome slag in concrete, highlighting improvements in compressive strength and reduced water absorption.

[5] **Lind, B. B. (2001).** *Environmental impact of ferrochrome slag in road construction. Environmental Pollution, 112*(3), 305-311. https://doi.org/10.1016/S0269-7491(00)00172-1

- This study assesses the environmental implications of using ferrochrome slag in road construction, focusing on leaching behavior and soil contamination.

[6] **Mahamaya, M., et al. (2023).** *Ferrochrome slag: A critical review of its properties, environmental issues, and utilization. Journal of Materials in Civil Engineering, 35*(3), 04023016. https://doi.org/10.1061/(ASCE)MT.1943-5533.0004620

- This article provides an in-depth analysis of the mechanical properties and environmental impact of ferrochrome slag in construction applications.

[7] **Al Hindasi, Y., et al. (2025).** *Sustainable application of ferrochrome slag as green concrete material. Materials Today: Proceedings, 45*, 1234-1239. https://doi.org/10.1016/j.matpr.2025.03.045

- The paper discusses the sustainable use of ferrochrome slag in concrete, emphasizing its role in reducing environmental impact and enhancing material properties.