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ORIGINAL PAPER

Durability and Strength Enhancement in Concrete Using Steel Slag as Fine Aggregate Replacement

Mohammad Afaque[1] · **Rizwan Ahmad Khan**[2] · **Surendra Roy**[1]

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Abstract
Steel slag, an industrial byproduct from steel manufacturing, is generated abundantly through electric arc furnaces (EAF) and basic oxygen furnaces (BOF), presenting a potential alternative to natural aggregates in the construction industry. The heightened scarcity of natural aggregates, alongside production and transportation challenges, accentuates the need for a more deliberate exploration of steel slag's applications. While steel slag is currently utilized as aggregate in hot mix asphalt, its potential as a replacement for both fine and coarse aggregates in conventional concrete remains underexplored and merits further investigation. With the majority of concrete comprising aggregates, the substitution of natural aggregates with steel slag holds substantial promise for environmental benefits. This study delves into the distinctive physical and chemical properties of metallurgical slags, exploring diverse possibilities for their application in industrial sectors and civil constructions. Specifically, the focus is on utilizing iron slag as a partial replacement for sand in concrete, showcasing integration avenues and highlighting potential advantages. The research evaluates concrete's strength and durability across replacement levels ranging from 0 to 50% of fine aggregates. Key metrics assessed include workability, compressive strength, tensile strength, water permeability, and rapid chloride permeability. The findings demonstrate significant enhancements in concrete properties with iron slag substitution, highlighting its potential to support sustainable construction practices and improve environmental outcomes in concrete production.

Keywords Compressive strength · Iron slag · Rapid chloride permeability · Sustainability · Natural aggregates

Introduction

Slag, a glass-like byproduct formed during metal extraction, has a long history of industrial application, evolving from its early uses in medicine to its utilization in diverse sectors such as construction. Over time, its significance has grown, exemplified by its incorporation into structures like cannonballs in Germany (1589), wharf buildings in England (1652), and armored concrete in Germany (1852–1892), culminating in the production of slag bricks in Japan (1901) and the widespread adoption of iron and steel slag in 2007. Initially considered a nuisance, the realization of slag's value led to its widespread adoption across Europe and beyond, where markets for this industrial byproduct flourished.

In contemporary research, the utilization of slag aggregates in concrete production has emerged as a promising avenue for enhancing both performance and sustainability. Studies by Pattanik et al. (2021), Murmu et al. (2023), and Baalamurugan et al. (2024) have highlighted significant benefits, including a notable decrease in concrete density, minimal differences in compressive strength (CS) and splitting tensile strength (STS), and superior properties in concrete specimens containing slag aggregate. Investigations by Dong and Chen (2022) and Papachristoforou et al. (2020) have emphasized the advantages of slag aggregate over natural aggregates, such as enhanced concrete strength and improved interfacial transition zone (ITZ) properties.

Moreover, research by Han and Zhang (2018), Roslan et al. (2020), Palankar et al. (2016), and Adegoloye et al. (2016) has demonstrated the efficacy of incorporating slag aggregates in concrete mixes, resulting in significant strength gains without compromising material integrity.

✉ Rizwan Ahmad Khan
krizwan.cv@amu.ac.in

[1] Department of Civil Engineering, Babu Banarasi Das University, Uttar Pradesh, Lucknow, India

[2] Department of Civil Engineering, Faculty of Engineering &Technology, AMU, Uttar Pradesh, Aligarh, India

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