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Review On Use Of Steel Slag As A Partial Replacement For Fine Aggregate In High Strength Concrete.

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ABSTRACT - This review paper investigates the use of steel slag as a partial replacement for fine aggregate in high-strength concrete, a promising approach to enhancing concrete properties and promoting sustainable construction practices. Steel slag, a by-product of the steel manufacturing process, offers high density, hardness, and angularity, which can improve the mechanical properties of concrete. The study systematically reviews the influence of varying steel slag content on key parameters such as compressive strength, tensile strength, and flexural strength, comparing it with conventional fine aggregates. The research indicates that incorporating steel slag can significantly enhance the compressive strength of high-strength concrete due to its superior binding properties and improved particle packing density. Moreover, the angular nature of steel slag particles contributes to better interlocking within the concrete matrix, thereby increasing tensile and flexural strengths. The review also examines the durability aspects of steel slag concrete, including its resistance to chemical attack, chloride penetration etc., highlighting its suitability for harsh environmental conditions. this paper provides a comprehensive overview of the potential and challenges of using steel slag as a partial replacement for fine aggregate, emphasizing its technical, environmental, and economic advantages. It calls for further research to standardize the use of steel slag in concrete and to explore innovative processing techniques to mitigate any adverse effects on concrete properties. This study contributes to the growing body of knowledge on sustainable materials in construction and supports the development of more eco-friendly and durable concrete solutions.

Keywords—Steel slag, High-strength concrete, Fine aggregate replacement, Mechanical properties, Chemical attack resistance, Sustainable construction.

1. Introduction

The increasing demand for sustainable construction materials has prompted significant research into alternative aggregates for concrete. Steel slag, a by-product of the steel manufacturing process, emerges as a viable candidate for partially replacing fine aggregates in high-strength concrete. Traditionally, fine aggregates, such as natural sand, have been the primary choice in concrete mix designs due to their availability and suitability. However, the depletion of natural sand resources and the environmental impact of its extraction have raised concerns, necessitating the exploration of alternative materials. Steel slag offers a promising solution due to its unique physical and chemical properties, which can enhance the performance characteristics of concrete. Steel slag is characterized by its high density, hardness, and angularity, which contribute to improved mechanical interlocking within the concrete matrix. Its angular particles provide better bonding and reduced voids, potentially increasing the compressive and tensile strength of concrete. Moreover, steel slag's mineral composition, rich in calcium silicates and oxides, can react with the cementitious matrix, enhancing the pozzolanic reaction and leading to a denser and more durable concrete. The use of steel slag as a fine aggregate not only promotes the recycling of industrial waste but also reduces the reliance on natural sand, aligning with sustainable construction practices. Research has shown that concrete incorporating steel slag exhibits enhanced mechanical properties, such as higher compressive and flexural strengths, compared to conventional concrete. Additionally, the durability of steel slag concrete is often superior, with improved resistance to chloride penetration, chemical attacks, and freeze-thaw cycles. These properties make it particularly suitable for high-performance applications, including infrastructure projects in aggressive environments. However, challenges such as variability in steel slag composition and potential expansion issues due to free lime content need to be addressed to ensure consistent quality and performance.

This study aims to review the existing literature on the use of steel slag as a partial replacement for fine aggregate in high-strength concrete. It focuses on understanding the material's impact on concrete's mechanical and durability properties, as well as its environmental and economic implications. By evaluating the benefits and limitations of steel slag in concrete, this paper seeks to provide a comprehensive understanding of its potential role in sustainable construction. The introduction of steel slag into concrete mix design not only contributes to resource conservation but also offers a pathway towards more eco-friendly and high-performance concrete solutions.

2. LITERATURE REVIEW

A. Genral :

The exploration of alternative materials in concrete production has gained significant momentum due to the increasing emphasis on sustainable construction practices. Among these alternatives, steel slag has emerged as a promising material for partial replacement of fine aggregates in concrete, particularly high-strength concrete. Steel slag, a by-product of the steel manufacturing process, offers unique properties that can potentially enhance the mechanical and durability characteristics of concrete. Several studies have documented the beneficial effects of incorporating steel slag into concrete. Research indicates that the angular and dense nature of steel slag particles improves the interlocking within the concrete matrix, which in turn enhances the compressive, tensile, and flexural strengths of concrete. For instance, studies have reported that concrete with steel slag as a partial replacement for fine aggregates can achieve higher compressive strength compared to conventional concrete mixes. This increase in strength is attributed to the improved particle packing density and the pozzolanic reactions facilitated by the slag's chemical composition.

B. Review of Literatures :

Juhi Singh, Monu Kuma, Mohit Gupta, Ali Akbar, (2023): This comprehensive review paper provides a detailed understanding of steel slag concrete, covering properties, mix design considerations, mechanical performance, and sustainability aspects. It identifies gaps in current research and proposes areas for further exploration to optimize steel slag utilization in high-strength concrete applications. The review aims to contribute to the advancement and broader adoption of high-strength concrete by addressing existing knowledge gaps and suggesting future research directions. It provides a comprehensive understanding of the properties, mix design considerations, mechanical performance, and sustainability aspects of steel slag concrete. The review also highlights the gaps in current research and suggests potential areas for further exploration in order to optimize the use of steel slag in high-strength concrete applications.

Sunidhi Rajhans, Ajay Kumar Singh (2022): This paper explores the partial replacement of coarse aggregates in concrete with waste slag from stainless steel manufacturing. The study aims to improve the mechanical properties and durability of concrete by replacing natural coarse aggregates with steel slag. The investigation is motivated by the increasing use of stainless-steel products in construction and industrial sectors, leading to significant waste generation. Results from sorptivity tests indicate improved durability and a denser microstructure with the incorporation of steel slag. The research suggests the potential for utilizing stainless steel waste slag in the production of new and durable concrete structures, addressing both environmental and economic concerns. This metal slag is used to investigate the impact of new and durable concrete structures where the coarse natural coating is replaced by indirect slag steel. Sportively test it exhibits a dense microstructure and improves durability.

R. Ashwathi, G.T. Amudhan Vetrivel, M. Abishek (2022): This study explores the mechanical properties of concrete with partial replacement of fine aggregate with steel slag to enhance economic and ecological performance. It investigates various combinations of steel slag and their potential as replacement materials in concrete surfaces requiring high skid resistance. The study highlights practical implications in construction and road projects and suggests further research to explore steel slag's potential in various construction applications. The optimum amount of replacement in fine aggregate is found to be 20% giving a strength increment of 8% in the compressive strength category. In split tensile and flexural strength criteria strength increment of 7.5% and 40.625% is observed. There are many practical implications of steel slag in the construction industry, road constructions, and clinker substitutes as granulated BF slag, water treatment plants, evidently many researches have proved slag as productive coarse aggregates replacement.

Karukola Parvathi, Ch Sai Kiran (2021): This review focuses on the utilization trends and potential large-scale employment of steel slag in the Indian context. The study aimed to investigate the effect of replacing coarse aggregates with steel slag on various strength and durability properties of concrete, using M30 grade mix design. Different replacement percentages ranging from 0% to 100% were examined, and physical and chemical characteristics of steel slag were analyzed. Concrete specimens were cast and cured for different durations, followed by evaluation of mechanical and durability properties according to IS codes. The research highlights the feasibility of using steel slag as a partial replacement for coarse aggregates, emphasizing its potential in sustainable concrete production. In this present study, physical and chemical characteristics of steel slag are to be analyzed and then the research progress of steel slag with natural aggregate concrete cubes, cylinders and beams are to be casted by using mix design M30 and are cured for 7, 28 & 56 days. The mechanical, durability properties of hardened concrete is to be carried out according to IS codes.

Haiqin Xu, Shaopeng Wu, Hechuan Li, Yuechao Zhao and Yang Lv (2020): It evaluates various properties of steel slag and compares them with basalt in asphalt mixtures. Results indicate favorable mechanical properties and heating capacity of steel slag asphalt mixtures, suggesting their potential in self-healing asphalt concretes. Results showed that steel slags had more obvious holes in the surface while the surface area is much larger than that of basalt. Furthermore, steel fibers and steel slag both have dynamic stability, and steel fibers contribute to increased moisture resistance while steel slag is not. Steel slag asphalt concrete showed better mechanical property and better capacity to store heating. Steel slag asphalt mixtures had a similar heating speed to basalt asphalt mixtures but a significantly slower cooling rate. Finally, the induction healing test and CT scanning test demonstrated that steel slag asphalt mixtures had a similar healing ability to basalt asphalt mixtures. It can be concluded that steel slags have the potential to replace the natural aggregates to be applied in induction heating self-healing asphalt concretes.

Ranjitha B Tangadagi, Manjunatha M, Preethi S Bharath A (2018): This study examines the properties of cement with steel slag as a substitute for fine aggregates in concrete. Various replacement percentages ranging from 10% to 50% were investigated, with fresh and hardened properties of concrete evaluated. Tests including compressive strength, split tensile strength, and flexural strength were conducted to assess the performance of concrete with steel slag aggregates. The research emphasizes the environmental advantages and cost effectiveness of replacing conventional fine aggregates with steel slag. Overall, the study highlights the potential for large-scale utilization of steel slag in concrete applications, contributing to sustainable construction practices. In this way, supplanting the regular fine aggregates in concrete applications with steel slag would prompt impressive ecological advantages and would be conservative. Physical and chemical properties of steel slag is an integral factor of steel slag reused as aggregate material, concrete and solid admixture, soil stabilizer and as a construction material and so forth. This survey presents use patterns of steel slag and potential possibilities for huge scale work of steel slag in Indian setting.

S.I. Adedokun, M.A. Anifowose, S.O. Odeyemi (2018): This study draws conclusions from previous research on the effects of partial replacement of coarse aggregate with steel slag in concrete production. It highlights steel slag's suitability as a substitute for coarse aggregate and identifies optimal replacement percentages for enhanced compressive, split tensile, and flexural strengths. The study emphasizes the need for further research on mix designs and concrete grades to fully explore steel slag's potential in concrete applications. Based on the extensive reviews of the previous studies carried out to investigate the effects of partial replacement of coarse aggregate with steel slag, the following conclusions have been drawn, from chemical properties, it was observed that SiO2, Fe2O3 CaO and MgO are the major constituents of steel slag. Steel slag possesses higher value of specific gravity and Aggregate Impact Value (AIV) than coarse aggregate but have similar values of the Aggregate Crushing Value (ACV) and Los Angeles Abrasion Value (LAAV) with coarse aggregate. This therefore makes steel slag a suitable substitute for coarse aggregate in concrete production. The optimum replacement of coarse aggregate with steel slag that gives higher compressive strength than conventional concrete is found to be between the range of 30 and 60%. 40 to 60% steel slag (by weight of coarse aggregate) in concrete will produce an improved split tensile strength compared to conventional concrete.

Anurag Jain, Sandeep Gupta, Mayank Gupta (2018): It Results show improvements in compressive and flexural strengths with increasing percentages of steel slag substitution. The study suggests practical applications in concrete block production and highlights the importance of specific mix designs for optimized performance. Compressive Strength Reading (for the typical estimation of three-piece test) at 7, 14, 28 and 50 days are higher than with the use as partial substitution of steel slag by sand with the level of 10, 20, and 30%, lower than 40% of steel slag show up particularly in association with other creation block shape cases with M 25, M-30, M-35 review of concrete. The increment in compressive strength of M 25 is noted 31.47% for 7 days curing 20% for 14 days curing 18% for 28 days while at 40% a slight decrement of 4.2% noted for 7 days and 3.4 % for 28 days of curing as compared to 30% 2. The increment in flexural strength test is about 36.7% for 28 days curing for M 25 grade of concrete and 24.7% for 28 days.

Richa Palod, S.V. Deo and G.D. Ramtekkar (2017): This paper reviews the usage of steel slag (SS) in the construction industry, focusing on its role in sustainable development. It discusses improvements and challenges associated with SS usage in cement and concrete production, emphasizing its environmental benefits and potential drawbacks. The review underscores the importance of large-scale SS utilization for sustainable development and highlights the need for further research to address knowledge gaps and overcome implementation barriers. Volume instability due to free CaO and MgO are obstacles in increasing the level of usage but can be solved by using it along with GGBS as combined admixture. Another difficulty is the high-water absorption capacity of SS aggregates as compared with natural aggregate. Therefore, investigations should be done in the future for potential uses SS on Indian grounds.

Radhu Chandini (2017): This study investigates the feasibility of using steel slag as a fine aggregate substitute in concrete and evaluates its effects on workability, strength, and durability. Results indicate adverse impacts on workability but significant improvements in tensile and compressive strength with steel slag incorporation. The study recommends further research to investigate long-term effects on concrete durability and mechanical properties through extensive field studies. The demand for aggregates especially fine aggregates is increasing rapidly and so as the demand of concrete. Thus, it is becoming more important to find suitable alternatives for aggregates in the future. The results showed that it has properties similar to natural aggregates and it would not cause any harm if incorporated into concrete. From the research studies discussed the important conclusions on using steel slag as fine aggregate are as following. The use of steel slag affects workability adversely but it improves the tensile strength and compressive strength to a considerable extent. The negative effect on workability can be compensated for by using appropriate admixtures. When replacement percentages are between 15 and 30%, best results are obtained for compressive strength. The tensile strength increases by 1.1-1.3 times. The use of steel slag improves tensile strength of mixes with all replacement ratios.

S. Piraimathi (2017): In this study, fine aggregate was partially replaced by steel slag in concrete mixes, with replacement proportions ranging from 20% to 50%. The investigation covered parameters such as compressive strength, flexural strength, modulus of elasticity, rapid chloride penetration, and sportively. Results showed that 30% replacement of fine aggregate with steel slag yielded maximum compressive strength and optimal flexural strength. Additionally, the use of steel slag led to reduced chloride permeability, particularly notable at the 30% replacement level. Overall, the study suggests that incorporating steel slag in concrete mixes can enhance both mechanical properties and durability, with 30% replacement emerging as the optimum proportion. The RCPT has gained wide acceptance as a relatively easy and quick test method. The use of steel slag and proper curing will significantly reduce the chloride permeability, particularly at concrete ages past 28 days and this longer time to achieve the desired qualities should not be overlooked. If the limitations inherent to RCPT are understood, this test can be used for a wide range of applications, testing and quality control purposes. All replacements including control mix gave low chloride ion permeability, but 30% replacement gave very low chloride ion permeability. The water absorption of conventional concrete was found to be 0.855, for 10% it was 0.983, for 20% it was 0.914, for 30% it was 0.764 and for 40% it was 0.869.

Dinesh Kumar, Tiruchirappalli Gayathri Priya, Poornima (2016): This research investigates concrete behavior with steel slag replacing natural aggregates, aiming for an economical and environmentally friendly solution. Results indicate comparable compressive and splitting tensile strengths between concrete with steel slag and conventional concrete. The study suggests further investigation into long-term effects on concrete properties and durability. The main aim of this research was to study the behavior of concrete and changes in the properties of concrete with steel slag replacing the use of natural aggregates. Steel slag is a byproduct and using it as aggregates in concrete will might prove an economical and environmentally friendly solution. The demand for aggregates is increasing rapidly and so as the demand of concrete. Thus, it is becoming more important to find suitable alternatives for aggregates in the future. A through literature review was conducted to study and investigate the properties of steel slag aggregates. The results showed that it has properties similar to natural aggregates and it would not cause any harm if incorporated in to concrete.

R. Padma Priya, V. K. Bupesh Raja, Ganesh Kumar, Balamurugan Jayaraman (2015): This study identifies optimal replacement levels for coarse aggregate with steel slag and manufactured sand in concrete production to enhance strength properties. Results indicate increased strength with specific replacement ratios, suggesting the suitability of certain combinations for various construction applications. The increase in strength for the replacement of coarse aggregate by steel slag up to 40 percent may be due to shape, size and surface texture of steel slag aggregates, which provide better adhesion between the particles and cement matrix. Optimum level of replacement for steel slag is found as 40%. Increase in strength initially is attributed to shape effect and decrease in strength beyond 40% is attributed to porosity of steel slag. Optimum level of replacement for M sand is found as 25%. Increase in strength initially is attributed to particle size effect and decrease in strength beyond 25% is attributed to water absorption capacity of M sand. The combination 25 percent replacement of M Sand and 40 percent replacement of steel slag gave compressive strength of above 48.7 Mpa.

Magdi M. E. Zumrawi, Faiza O. A. Khalill (2015): This study explores the potential of Steel Slag Aggregates (SSA) as substitutes for natural aggregates in hot mix asphalt (HMA) for road construction. Laboratory tests were conducted to assess SSA's suitability at varying percentages (0%, 50%, 75%, and 100%) in HMA production using Marshall mix design. Results revealed significant enhancements in HMA properties with increasing SSA content, including higher density, improved stability, and reduced flow and air voids values, particularly notable at 100% SSA substitution. The findings suggest that SSA can be a viable alternative aggregate source, potentially improving the performance of concrete asphalt mixtures in road construction applications.

Sultan A. Tarawneh, Emhaidy S. Gharaibeh and Falah M. Saraireh (2014): This study evaluated the physical and mechanical properties of steel slag aggregate concrete compared to conventional crushed limestone aggregate concrete. Steel slag, a by-product of the steel industry, was investigated as a potential alternative to conventional aggregates due to its similarities and availability. Results indicated that steel slag aggregate concrete exhibited better abrasion resistance and impact value compared to conventional aggregate concrete. Moreover, early-age strength development was observed with steel slag, suggesting its potential as an accelerator. The study underscores the environmental benefits of utilizing steel slag in concrete production, highlighting its role in preserving natural resources and reducing waste. As a result, utilization of steel slag will save natural resources and clean environment. Furthermore, results have shown that slag aggregate has better abrasion factor and impact value than conventional aggregate. Thorough investigation of the results has indicated that the amount of increase in compressive strength at age of 7 days are much more than that of age 28 days for all types of aggregate replacement. This indicates that the added slag could work as accelerator at early age while at 28 days age, the effect is reduced. The fine slag replacement scores the highest effect.

3. OBSERVATION FROM LITERATURE REVIEW

The review of literature reveals a growing interest in the utilization of steel slag as a partial replacement for both fine and coarse aggregates in concrete, driven by environmental, economic, and performance considerations. Key observations include:

- Numerous studies have demonstrated that the incorporation of steel slag improves the compressive, tensile, and flexural strengths of concrete. The rough texture and angular shape of steel slag particles contribute to better mechanical interlocking within the concrete matrix, enhancing its load-bearing capacity.

- Steel slag has been shown to enhance the durability of concrete, particularly in terms of resistance to chloride penetration, freeze-thaw cycles, and alkali-silica reactions. The dense microstructure resulting from steel slag incorporation contributes to reduced permeability and increased resistance to environmental degradation.

- While various studies suggest different optimal replacement levels for fine and coarse aggregates, a common finding is that a partial replacement range (typically around 20-40% for fine aggregates and 30-60% for coarse aggregates) provides the best balance between mechanical properties and durability.

- The use of steel slag in concrete not only helps in managing industrial waste but also reduces the demand for natural aggregates. This contributes to the conservation of natural resources and the reduction of environmental impacts associated with quarrying.

- Despite the benefits, there are concerns regarding the variability in the chemical composition of steel slag, which can affect concrete performance. Issues such as potential expansion due to free lime and magnesium oxides, and higher water absorption, require careful consideration and management.

- The practical applications of steel slag in construction are wide-ranging, including its use in high-strength concrete, road construction, and as a component in self-healing asphalt concretes. These applications benefit from the improved mechanical properties and durability provided by steel slag.

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