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Analysis of Concrete by Using Silico Manganese Slag as a Partial Replacement of Fine & Coarse Aggregate – A Review

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ABSTRACT

Presently in India, due to limited modes of practices of utilization, huge amount of iron and Silico manganese slag dumped in yards of each production unit and engaging of important agricultural land and grave pollution to whole environment. This review presents utilization trends of Silico manganese slag and possible potentials for large-scale employment of Silico manganese slag in Indian context. This project aim is to study experimental investigation about the effect of partial replacement of coarse aggregates by Silico manganese slag (SMS), on the 0%, 5%, 10%, 15% & 20% strength and durability properties of concrete, by using the mix design of M30 grade. The optimum percentage of replacement of coarse aggregate by Silico manganese slag is found. This study is carried out to determine the feasibility of using Silico manganese slag as partial replacement for coarse aggregates of M30 grade with different replacement percentages i.e. (0%, 5%, 10%, 15%&20%). In this present study, physical and chemical characteristics of Silico manganese slag are to be analysed and then the research progress of Silico manganese slag with natural aggregate concrete cubes are to be casted by using mix design M30 and are cured for 7 days & 28 days. The mechanical properties of hardened concrete were to be carried out according to IS codes. For mechanical properties of concrete (i.e., Destructive Testing Compressive strength, & Non-Destructive Testing - Rebound hammer) are to be determined and investigated. By comparing the test results, it may be concluded that Silico manganese slag may be used as partial replacement of natural coarse aggregate in concrete.

Keywords: Manganese Slag; Concrete; Compressive strength; Rebound hammer; Compaction factor and Slump cone test.

I. INTRODUCTION

In construction work, there is a high demand for concrete, which is a homogeneous material formed by mixing Cement, Sand, and Aggregate in the presence of water. Cement serves as the binder material, while sand acts as a filler material, occupying the voids between the aggregate. Aggregate, which constitutes more than 70-80% of the total volume in concrete, provides strength to the structure.

The production of aggregate involves crushing stones in stone quarries, which requires significant manpower and mechanical equipment. However, this process generates small dust particles with low density that easily mix with air, leading to adverse environmental impacts and health hazards for workers on-site.

In India, the current practices of utilization result in the accumulation of large amounts of iron and steel slag in production yards, occupying valuable agricultural land and causing grave pollution to the environment. To address these challenges, an alternative solution is to replace the aggregate with silico manganese slag.

Silico manganese slag is a byproduct generated during the production of SiMn alloy, with approximately 1.2 to 1.4 tons of slag generated per ton of alloy produced. By utilizing this abundant source of silico manganese slag, it is possible to create silico manganese slag concrete, which consists of cement, sand, aggregate, and sieved silico manganese slag aggregate.

In this type of concrete, the crushed stone aggregate is partially or fully replaced with silico manganese slag, offering a means to utilize environmental sources and protect the environment. The main objective is to achieve the desired strength by experimenting with different percentages of silico manganese slag in the concrete mixture.

II. LITERATURE SURVEY

Abdulazeez Rotimi (2023), According to existing literature, cement is recognized as the key component in concrete, serving as a binding material. However, it has also been identified as the second-largest industrial source of CO2 emissions worldwide. This has spurred global efforts to find environmentally friendly alternatives to replace cement and protect the environment partially or fully. To address this concern, an experimental investigation was conducted in this study to assess the compressive and flexural strength of concrete when cement was partially substituted with Ground Granulated Blast Furnace Slag (GGBS). Concrete specimens were prepared with varying percentages of cement replacement, including 0%, 5%, 10%, 20%, 30%, and 40% with steel slag. These specimens were then subjected to analysis. The tests were conducted after 7 and 28 days of curing. The results of this study indicate that at 28 days, there was a decrease of 14% in compressive strength and 10.5% in flexural strength for specimens with 10% cement replacement compared to the control specimens. For specimens with 20% cement replacement, the decrease in compressive and flexural strength was 25.5% and 31% respectively. Nevertheless, it was observed that steel slag has the potential to partially replace cement, particularly when it is crushed into smaller particles that pass-through BS sieve #200.

Maohui Li, et al. (2023), The study investigated the impact of mechanical excitation, alkaline excitation, and salt excitation methods on the cementitious activity of alkaline steel slag. The research also examined the influence of grinding time, chemical activators, and steel slag content on the properties of cement when replaced by steel slag. XRD and SEM analyses were conducted to analyse the hydration products of cement replaced by steel slag. The findings indicate that steel slag's particle size distribution and cementitious activity is effectively enhances by mechanical excitation. The best mechanical properties were achieved when the grinding time was 20 minutes and the steel slag content was 10%. Furthermore, chemical excitation, combined with mechanical stimulation, further improves the cementitious activity of steel slag. The optimal mechanical properties were observed when the dosage of sodium hydroxide was 1.0%, the dosage of early strength agent was 2.0%, and the dosage of steel slag was 25%. Calcite, calcium hydroxide, dicalcium silicate, and C-S-H gel are the main hydration products of cement replaced by steel slag. The microstructure demonstrates a fibrous network structure, which forms the basis for enhancing mechanical properties. Overall, these findings highlight the potential of improving the properties of cement by incorporating steel slag, particularly through mechanical and chemical excitation methods.

Ashkar Rahman Aquib, et al. (2023), The transportation and highway industries are increasingly adopting sustainable practices by incorporating recycled materials to reduce their reliance on natural resources. One such material is steel-furnace slag, a by-product of steel manufacturing that is commonly disposed of in the environment, leading to pollution. However, due to its disposal costs and favourable characteristics, many countries now consider it a valuable construction material rather than industrial waste. The reuse of steel slag helps conserve natural resources and decreases the need for landfills. Steel slag has proven to be an excellent material for road construction, surpassing natural aggregates in various aspects such as skid resistance, rutting resistance, moisture damage resistance, and fatigue resistance. This paper focuses on examining the benefits of using steel slag in road construction while also assessing any potential adverse effects. Additionally, it provides a comparative analysis of different types of slag to determine their suitability for road construction. By utilizing steel slag in road construction, the transportation and highway industries can achieve sustainability goals, reduce environmental impact, and improve the performance of road infrastructure.

Shengjie Teng, et al. (2023), The volumetric stability of steel slag mortar and steel slag concrete is influenced by the proportion of natural sand replaced by steel slag sand. However, the current detection method for determining the steel slag substitution rate is inefficient and lacks representative sampling. To address this issue, a deep learning-based method for detecting the steel slag sand substitution rate is proposed. The proposed technique incorporates a squeeze and excitation (SE) attention mechanism into the ConvNeXt model to improve the extraction of colour features from steel slag sand mixtures. Additionally, the model's accuracy is further enhanced using the migration learning method. Experimental results demonstrate that the SE attention mechanism effectively assists the ConvNeXt model in extracting colour features from images. The model achieves an accuracy of 87.99% in predicting the replacement rate of steel slag sand, surpassing the original ConvNeXt network and other standard convolutional neural networks. Moreover, when applying the migration learning training method, the model achieves an accuracy of 92.64% in predicting the steel slag sand substitution rate, representing a 4.65% improvement in accuracy. The SE attention mechanism and migration learning training method contribute to the model's ability to better acquire critical features from the images, resulting in enhanced accuracy. The proposed method offers a quick and accurate means of identifying the steel slag sand substitution rate, making it suitable for steel slag sand substitution rate detection applications.

NgieHing Wong, et al. (2022), SiMn slag, a by-product of ferromanganese and silicomanganese alloy production, presents challenges in its disposal due to its large quantities and potential environmental pollution. This study aims to examine the physical and chemical characteristics of SiMn slag and explore its potential uses as construction materials through a systematic review. Twenty articles were selected and evaluated based on the slag's properties and its benefits when reused in construction. The literature indicates that SiMn slag from five countries shares similar chemical compositions, including SiO2, Al2O3, CaO, MnO, MgO, FeO+Fe2O3, and K2O+Na2O, at comparable levels. Two types of slag, air-cooled and water-quenched SiMn slag, exhibit distinct physical characteristics for reuse. SiMn slag has been effectively converted into diverse construction materials in recent research, including bricks, binders/cement, pastes, mortars, concrete, backfill materials, and manganese extracts. The effectiveness of utilizing SiMn slag as a recycled construction material depends on cooling methods, moisture content, particle size, equipment, energy requirements, and cost considerations. Research suggests four steps to enhance the reuse of SiMn slag, including waste management, pre-treatment, physical/chemical treatment, and product development. Furthermore, the investigation proposes implications and recommendations for future studies, such as developing large-scale recycling applications, implementing environmentally friendly disposal methods for SiMn slag, and assessing the practicality and feasibility of Silico manganese-slag-based products in real-world projects.

Karukola Parvathi, et al. (2021), Steel slag is a byproduct of steelmaking and steel refining processes. In India, a significant amount of iron and steel slag is currently being dumped in yards, occupying valuable agricultural land, and causing environmental pollution due to limited utilization practices. This review examines the trends in steel slag utilization and explores the potential for large-scale employment of steel slag in the Indian context. The objective of this project is to conduct an experimental investigation on the impact of partially replacing coarse aggregates with steel slag (SS) in concrete. The mix design used is for M30 grade concrete. The study aims to determine the optimum percentage of coarse aggregate replacement with steel slag. The feasibility of using steel slag as a partial replacement for coarse aggregates in M30 grade concrete is evaluated in this study. Various replacement percentages (0%, 25%, 50%, 75%, and 100%) are considered. The physical and chemical characteristics of steel slag are analysed, and concrete cubes, cylinders, and beams are cast using a mix design for M30 grade concrete. The specimens are cured for 7, 28, and 56 days, and the mechanical and durability properties of hardened concrete are assessed in accordance with relevant IS codes. The mechanical properties, such as compressive strength, split tensile strength, and flexural strength, are determined, and durability properties, including acid attack, drying shrinkage, and indirect carbonation, are investigated. Additionally, the study explores the use of Fibers to enhance the strength of concrete mixes with maximum steel aggregate replacement. By comparing the test results, it can be concluded that steel slag can be used as a replacement for natural coarse aggregate in concrete.

Abhijit Warudkar, et al. (2020), The potential of waste steel slag to use as a replacement of coarse aggregate in cement concrete was observed. We observed that the mixing of waste steel slag with concrete improves the mechanical and durability properties of the concrete. The abrasion properties of steel slag concrete are analogous with a coarse aggregate concrete. The study concludes that the use of steel slag in concrete improves the physical properties of the cement concrete. Thus, steel slag concrete can be used for the building floorings, pavements, or concrete surfaces which are exposed to the external forces and severe all weathers conditions.

Kiran Kumar Poloju, et al. (2020), This paper discusses the advantages of incorporating marble powder into concrete technology, as it has a significant impact on concrete properties and provides maximum workability compared to conventional concrete. The main objective of this study is to assess the feasibility of using marble powder as a substitute in concrete to improve its quality properties. In this study, marble dust powder was added to M25 grade concrete at various proportions (0%, 10%, 20%, and 30%) by weight of the concrete. Several tests were conducted, including slump test, compression test, split tensile test, flexural test, and rebound hammer test, to evaluate the properties of fresh concrete. The results were then compared with those of traditional cement. Different sizes of moulds were used to determine the strength properties of the concrete. To gain insights into the strength properties of concrete, all the tests were conducted after 7 and 28 days of water curing. The test outcomes indicate that the performance in terms of compressive strength, split tensile strength, and durability is improved, and the optimal substitution level is determined to be 20%.

Hongbeom Choi, et al. (2020), When molten silicon manganese slag comes into contact with water, it rapidly cools down and forms porous rock masses resembling volcanic rock, due to the release of water vapor. This porous rock has the potential to be used as a lightweight aggregate in construction applications. The aim of this study was to evaluate the engineering properties of this material for construction purposes. In terms of engineering properties such as low density, low water absorption, and regular shape, the aggregate cooled by air-water mixture was found to be superior to other cooling conditions. The size of the pores in the aggregate was found to vary depending on the ratio of air to water, with higher water ratios resulting in larger average pore sizes. The pore size and volume directly affect the properties of mortar, and using air-water mixed rapid-cooled aggregates in mortar resulted in lower dry shrinkage. In terms of mortar engineering properties, the mortar with air-water mixed rapid-cooled aggregates exhibited favourable characteristics, including a unit weight of 1,682 kg/ m^3 and compressive strength of 22.9 MPa. These results suggest that this lightweight aggregate has the potential to be used as a structural lightweight aggregate, considering its suitable properties for construction applications.

S. Ganesh, et al. (2018), In this study, the effect of replacement of coarse aggregate by silico manganese slag on mechanical properties and durability properties of concrete was examined. In this study, the mix design considered is M30 grade of concrete. The natural coarse aggregate was replaced by silico manganese slag at different levels: 0%, 25%, 50%, 75%, and 100%. The mixes were designated as SMS 25, SMS 50, SMS 75, and SMS 100 for the respective replacement levels. Additionally, the effect of Fibers on the compressive strength of concrete was investigated. At a 50% replacement level of coarse aggregate with silico manganese slag, the study found that the optimum strength was obtained. Concrete with the replacement of coarse aggregate by silico manganese slag (SMS 50) exhibited similar mechanical properties, including compressive, split tensile, and flexural strength, compared to conventional concrete. Moreover, when the (SMS 50) mix was immersed in acids and alkalinity, it showed very low weight and strength loss, in contrast to the control concrete mix. Furthermore, the addition of Fibers to concrete containing coarse aggregate with steel slag improved their mechanical properties.

Liwu Mo, et al. (2017), The author studied different aspects of concrete, as follows: 60% of steel slag powders containing high free-CAO content, 20% of Portland cement, and up to 20% of reactive magnesia and lime were mixed to prepare the binding blends.

Different durations of carbonation curing (1 day, 3 days, and 14 days) were employed on the concrete, exposing it to a concentration of 99.9% CO2 and a pressure of 0.10 MPa. Following this, the resulting binding blends were utilized to cast concrete, with steel slag aggregates replacing natural aggregates (limestone and river sands) up to 100%. The investigation primarily emphasized several aspects of the concrete, including the carbonation front, carbonate products, compressive strength, microstructure, and volume stability. The results showed that the compressive strength of the steel slag concrete significantly increased after CO2 curing. For 14 days of CO2 curing, the compressive strengths of the concrete were up to five times higher compared to the corresponding concrete cured conventionally with moisture for 28 days. The accelerated carbonation of steel slag presents a promising method for producing low-carbon concrete, as highlighted in the author's study. Furthermore, the utilization of steel slag aggregates in lieu of limestone and sand aggregates resulted in enhanced compressive strengths during the CO2 curing.

Najamuddin Syed Khaja, et al. (2017), Concrete is the most used construction material worldwide, and its demand continues to grow due to the expanding vision of growth in the construction sector. Portland cement, serving as the binder, is a primary component of concrete. However, the production of cement contributes significantly to greenhouse gas emissions. The release of CO2, a major greenhouse gas, contributes to global warming and climate change. Approximately 900 kg of CO2 is generated for every 1000 kg of cement produced. To meet the increasing demand in the construction sector and achieve emission reductions, alternative cementitious materials need to be utilized. One approach to address this issue is by replacing cement with supplementary cementitious materials (SCMs) obtained as by-products from various industries or available natural resources. Industrial by-products such as Cement Kiln Dust (CKD), Limestone Powder (LSP), Electric Arc Furnace Dust (EAFD), Heavy Oil Fuel Ash (OA), and Silico Manganese Slag (SiMn) can be effectively utilized as replacements for cement in concrete. This not only helps in reducing cement consumption but also provides a safe disposal solution for industrial waste, promoting sustainable growth. This paper aims to review the research conducted by various scholars on the use of SCMs as partial replacements for cement in concrete. By incorporating these SCM materials into concrete mixtures, researchers have explored the potential benefits of reducing cement content while maintaining concrete performance and contributing to sustainable development.

Ravikumar H, et al. (2015), The experimental investigation carried out in the construction industry involved replacing the normal coarse aggregate with steel slag to evaluate the effects of concrete. Concrete, being the most widely used material worldwide, is unavoidable, but there is an increased scarcity of aggregate nowadays. For many years, industrial waste such as fly ash, silica fume, and steel slag were considered waste materials; however, they have been successfully used in the construction industry to substitute concrete partially or fully. This study considered concrete of M20, M30, M40, and M50 grades, respectively, with water-to-cement ratios of 0.55, 0.45, 0.37, and 0.32. Coarse aggregate was replaced by steel slag at 30%, 60%, and 100%. The results of this study revealed an improvement in compressive strength by 5% to 10% for all concrete grades. Additionally, there was a 4% to 8% increase in split tensile strength and a 2% to 6% increase in flexural strength for all grades of concrete. Steel slag can be used up to a 60% replacement in all grades of concrete, but full replacement significantly decreases the strength.

V. Subathra Devia, et al. (2014), The investigated effect of partial replacement of coarse and fine aggregates by steel slag (SS) on the various strength and durability properties of concrete, using the mix design of M20 grade, the optimum percentage of replacement of fine and coarse aggregate by steel slag was found. Gradually, as the percentage of replacement increases, the workability of concrete decreases, which is determined using the slump test. Compressive strength, tensile strength, flexural strength, and durability tests such as acid resistance using HCL, H2SO4, and rapid chloride penetration are experimentally investigated. For conventional concrete, the results indicate that the compressive, tensile, and flexural strength improves with the partial replacement of fine and coarse aggregates by steel slag. For both replacements, the deflection in the RCC beams gradually increases as the load on the beam increases, while the mass loss in cubes after immersion in acids is found to be very low. Based on the limits given in ASTM C 1202, the degree of chloride ion penetrability is assessed. The viability of using SS in concrete is established.

Liang Duoqiang, et al. (2011), Manganese slag can be incompletely substituted to cement concrete to lower profitable cost and achieve enhanced mechanical performances. The cement concrete added lower than 30 by manganese slag was not changed significantly, while the ordinary Portland cement added lower than 30 by manganese slag was bettered in mechanical performances.

III. CONCLUSION

The future scope of using silico manganese slag as a partial replacement of fine and coarse aggregate at different percentages (5%, 10%, 15%, and 20%) holds great promise and potential. As research in this area continues to advance, several key aspects are worth exploring:

1. Improved Concrete Mix Design: Further research can focus on optimizing the concrete mix design with different percentages (e.g., 30%, 40%, 50%, 60%, 70%, 80%, 90%, and 100%) of silico manganese slag. The goal is to identify the ideal combinations that offer the best compromise between strength, workability, and durability while minimizing any negative effects on concrete performance.
2. Performance under Specific Conditions: Investigating the performance of concrete containing silico manganese slag under various environmental conditions (e.g., high temperatures, aggressive chemical environments, and freeze-thaw cycles) is essential. Understanding how this partial replacement affects concrete properties in these scenarios will guide its usage in specific construction applications.
3. Long-Term Durability Studies: Long-term durability studies are crucial to assess the aging and performance of concrete containing silico manganese slag. Evaluating the concrete's behaviour over extended periods will help ensure its stability and longevity, making it more viable for infrastructure projects.
4. Strength Enhancement Techniques: Research can explore potential additives or treatments that can enhance the strength of concrete when using silico manganese slag as a partial replacement. These techniques could address any strength reduction issues associated with higher slag percentages.
5. Sustainable Concrete Practices: The use of silico manganese slag aligns with sustainable concrete practices by reducing the consumption of natural aggregates and utilizing industrial by-products. As sustainability becomes a greater focus in the construction industry, further research and development in this area can lead to wider adoption.
6. Standardization and Guidelines: As the use of silico manganese slag in concrete gains traction,

there is a need for standardized testing procedures and guidelines to ensure consistency and reliability in concrete mixtures across different projects.

7. Economic Feasibility Studies: Detailed economic feasibility studies can be conducted to evaluate the cost-effectiveness of using silico manganese slag as an aggregate replacement. Assessing the overall cost savings and potential benefits will encourage its implementation in real-world projects.
8. Green Building Certifications: Research on the environmental benefits of using silico manganese slag in concrete can facilitate its recognition and acceptance in green building certifications and sustainable construction programs.
9. Large-Scale Field Trials: Real-world implementation and large-scale field trials of concrete mixes with varying percentages of silico manganese slag will help validate the laboratory findings and provide valuable insights into practical challenges and advantages.

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