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# A Review on Engineering Behaviour of Sustainable Concrete with Steel Mill Scale and the Effect of Admixture on Workability Improvement

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**Abstract:** *The integration of chemical admixtures and alternative materials in concrete production has become a focal point in advancing construction technologies. This study investigates the combined effects of superplasticizers and mill scale on the workability and compressive strength of M30 grade concrete. Three different superplasticizers—Auramix 200, SikaPlast®-3069 NS, and Master Polyheed 8126—are evaluated for their performance enhancements in concrete. Additionally, mill scale, an industrial by-product, is utilized to partially replace sand in varying proportions (0%, 20%, 40%, 60%, 80%, and 100%) to assess its viability as a sustainable aggregate alternative.*

*The experimental phase is divided into three stages: initially assessing the workability and compressive strength of M30 concrete without admixtures; subsequently incorporating mill scale to observe its effect on concrete properties; and finally combining mill scale with each superplasticizer to maintain workability while evaluating the compressive strength. Slump cone tests are conducted to measure workability, and compressive strength tests are performed at 7, 14, and 28 days.*

*Results indicate that the inclusion of superplasticizers significantly enhances workability, with Auramix 200 showing the highest improvement. The addition of mill scale up to 60% replacement level increases compressive strength, with a notable peak at 60% replacement for both plain and superplasticizer mixes. However, higher replacement levels (80% and 100%) result in reduced strength and workability. Among the superplasticizers, Auramix 200 exhibits the best overall performance in conjunction with mill scale.*

*This study concludes that the strategic use of superplasticizers and mill scale can produce high-performance, sustainable concrete. Future research should explore long-term durability aspects and optimize mix designs for broader applications in construction.*

**Key words;** Mill Scale, Aggregate, Concrete admixture

## I. INTRODUCTION

The construction industry is continuously evolving, with ongoing research and development aimed at enhancing the properties and performance of concrete. One of the most significant advancements in concrete technology is the development and use of chemical admixtures, such as superplasticizers, to improve workability and strength. Concurrently, the search for sustainable and cost-effective materials has led to the exploration of industrial by-products, like mill scale, as partial replacements for traditional aggregates in concrete mixes.

This literature review paper delves into the dual approach of utilizing chemical admixtures and mill scale in concrete production. Superplasticizers, particularly the new generation ones based on polycarboxylate ether (PCE) technology, have shown remarkable improvements in concrete properties. Their ability to significantly reduce water content while maintaining or enhancing workability makes them indispensable in modern concrete technology. On the other hand, mill scale, a by-product of the steel manufacturing process, offers a potential alternative to sand in concrete mixes, aligning with the sustainability goals of reducing waste and conserving natural resources. The review aims to provide a comprehensive overview of existing studies and research findings related to the use of superplasticizers and mill scale in concrete. It examines the impact of these materials on the fresh and hardened properties of concrete, including workability, compressive strength, durability, and other mechanical properties. Additionally, the paper explores the synergetic effects of combining superplasticizers with mill scale, aiming to highlight the potential benefits and challenges associated with this innovative approach.

By synthesizing the current state of knowledge, this literature review seeks to identify gaps in the existing research and propose future directions for study. The ultimate goal is to contribute to the advancement of sustainable and high-performance concrete technologies, promoting the adoption of innovative materials and admixtures in the construction industry.

## II. LITERATURE REVIEW

Sreelakshmi G et al (2023) present a comprehensive overview of Self-Compacting Concrete (SCC) and its application in combination with Steel Mill Scale (SMS). In the current construction industry scenario, the demand for large and complex structures often leads to challenging concrete conditions. When dealing with significant amounts of heavy reinforcement in reinforced concrete (RC) elements, achieving full compaction without voids and honeycombs becomes difficult. Traditional methods such as manual compression or the use of mechanical vibrators prove inadequate in such situations. To address this issue, a new type of concrete known as self-compacting concrete (SCC) was developed. SCC exhibits excellent flowability, allowing it to easily surround reinforcement bars (rebar) and fill the intricate corners of formwork.

- In this study, the researchers focused on the utilization of steel mill scale, a waste product from the steel manufacturing industry, as a partial substitute for sand in SCC. Steel mill scale is known to have adverse environmental impacts, but it has shown promise as a substitute for fine aggregates in the construction sector. The research involved varying the replacement rate of steel mill scale (ranging from 0% to 100% by weight) in the fine aggregate content of M30 grade concrete. The resulting mixtures were compared against the original M30 concrete in terms of compressive strength, split tensile strength, flexural strength, and microstructural properties. The interaction between the mill scale and the concrete matrix was thoroughly investigated through microstructural studies.
- The study revealed that the fine particle size of the steel mill scale effectively filled the gaps between the fine and coarse aggregates, resulting in a denser concrete. The test results demonstrated that recycling steel mill scale as a minor substitute for fine aggregate offers a viable, cost-effective, and environmentally friendly solution. The optimum replacement rate was found to be 30%, as it achieved a balance between enhanced concrete properties and efficient utilization of the steel mill scale.
- This research provides valuable insights into the application of steel mill scale in SCC, highlighting its potential as a sustainable alternative in concrete production. By utilizing this waste product, the construction industry can contribute to environmental preservation while maintaining the desired performance and durability of concrete structures.

Sreelakshmi G et al (2023) This study explores the potential use of steel mill scales as a replacement for sand in construction applications. The research focuses on evaluating the effects of varying the proportion of steel mill scale substitution in M30 grade concrete. The study examines the microstructural characteristics and compressive strength of the concrete, as well as the interaction between steel mill scale and concrete. The anticipated outcomes include insights into the suitability of steel mill scales as a substitute for fine aggregates and their impact on concrete performance. The findings will contribute to the development of sustainable concrete mix designs and promote the responsible utilization of steel mill scales in the construction industry.

Sreelakshmi G et al (2023) This paper provides an overview of Self-Compacting Concrete (SCC) and explores the use of Steel Mill Scale (SMS) as a partial substitute for sand in concrete. The construction industry often faces challenges in achieving full compaction when dealing with heavy reinforcement in reinforced concrete structures. To address this issue, self-compacting concrete (SCC) was developed, which can easily flow around rebar and into tight corners without the need for manual or mechanical compaction.

In this study, the researchers tested steel mill scale, a waste product from the steel manufacturing industry, as a substitute for fine aggregates in construction. Different mixtures were prepared with varying replacement rates of steel mill scale (0%, 20%, 40%, 60%, 80%, and 100%) by weight in M30 grade concrete. The resulting mixtures were compared to the original concrete of the same grade. The study evaluated the compressive strength, split tensile strength, flexural strength, and microstructural properties of the concrete. The investigation focused on the interaction between the steel mill scale and the concrete matrix through microstructural analysis. The findings revealed that the small grain size of the steel mill scale effectively filled the gaps between the fine and coarse aggregates, leading to denser concrete. The test results demonstrated that recycling steel mill scale as a minor substitute for fine aggregate offers a viable, cost-effective, and environmentally friendly solution. The optimum replacement rate was determined to be 30%.

Roneh Glenn D. Libre Jr. (2022) conducted a study on the development of environmentally friendly construction materials to minimize carbon footprint. The study focused on utilizing abundant industrial wastes like Mill Scale waste (MS) and Fly-ash (FA) as replacements for Ordinary Portland Cement (OPC) in concrete production, aiming to reduce carbon emissions.

- The MS waste, generated from rolling mills of steel bars, was used as a partial replacement for FA in geopolymer paste. Different proportions of MS (20%, 30%, and 40%) were mixed with low calcium (Class F) FA, and various sodium hydroxide-to-sodium silicate (NaOH-to-WG) ratios (1:2.5, 1:2, and 1:1) were used. Unconfined compressive strength (UCS) tests were conducted on 50 mm x 50 mm x 50 mm cube specimens to evaluate the mechanical performance.
- The results showed that specimens with a 20% MS-to-FA ratio and a 1:2.5 NaOH-to-WG ratio exhibited higher UCS values. The study also recorded the setting time of the geopolymer mixes to analyze its relationship with the design mixes. Regression models using Response Surface Methodology (RSM) were developed to determine the desired UCS values. The study highlighted the significant environmental impact of concrete, which involves the mining and processing of billions of tons of natural materials each year.

M. A. Khan et al (2022) This paper focuses on the effective utilization of industrial waste steel mill scale in concrete. Various tests were conducted on concrete specimens with different percentages of steel mill scale (10%, 20%, 30%, and 40% by weight of sand) along with a control specimen. The results were evaluated based on workability, compressive strength, flexural strength, and durability.

- The findings revealed that the concrete incorporating 20% steel mill scale exhibited higher compressive and flexural strength compared to the control specimen and other replacement percentages. Additionally, it was observed that the durability and resistance against sulphate attack of the concrete improved with an increase in the proportion of mill scale replacement.
- Moreover, the higher specific gravity of mill scale waste makes it a suitable material for applications in heavyweight concrete members and radiation shield structures. This highlights the potential of steel mill scale as an effective and sustainable alternative in the production of concrete, contributing to waste reduction and improved performance in specific construction scenarios.

Sachin Tiwari (2022) Concrete is a widely used construction material, but its production requires a significant amount of natural aggregate, which has adverse environmental impacts. In this study, the physical and chemical properties of mill scale were characterized, revealing a high content of Fe<sub>2</sub>O<sub>3</sub>. The study then focused on partially replacing the fine aggregates in concrete with mill scale in different proportions to optimize strength characteristics. The maximum strength value was achieved at a 40% replacement of fine aggregate with mill scale. However, as the percentage replacement increased, the workability of the concrete decreased.

Kattekola Srikar and Dr. Marthi Kameswara Rao (2021) conducted a comprehensive study to evaluate the durability and corrosion resistance of concrete when steel mill scale is used as a substitute for fine aggregate. Various tests were performed including the Rapid Chloride Ion Penetration Test (RCPT), Sorptivity (water permeability), Acid Attack, Impressed Voltage test (Accelerated Corrosion), ultrasonic pulse velocity, electrical conductivity, and spectroscopic electron microscopy on cured concrete to analyze its internal structure.

- The findings of the study revealed that increasing the percentage of steel mill scale used as a replacement for fine aggregate in concrete led to improved strength of the hardened concrete. When steel mill scale was used at a replacement rate of 60%, it exhibited similar beneficial effects on strength and durability as other forms of reinforcement. However, it was noted that the workability of concrete with steel mill scale particles required additional water.
- The results also demonstrated a linear connection between the testing parameters of strength, durability, and microstructure. Based on these findings, it can be concluded that steel mill scale can be a viable and effective alternative to natural river sand in concrete production. Utilizing steel mill scale as a substitute for fine aggregate can contribute to the production of sustainable concrete with enhanced strength and durability, thereby addressing concerns related to solid waste disposal.

Yogesh Iyer Murthy (2021) conducted an experimental study to investigate the effects of partially replacing fine aggregate with mill scale in concrete. The mill scale was added in varying proportions by weight of the fine aggregate, ranging from 0% to 60%. The concrete was prepared using Portland Pozzolana Cement in the C20/25 grade.

- The physical and mechanical properties of the resulting concrete were evaluated. It was observed that as the percentage of mill scale replacement increased, there was a significant reduction in the slump of the fresh concrete. At 60% replacement, the slump was reduced by 74% compared to the control mix.

- Furthermore, the compressive, flexural, and split tensile strengths of the concrete also showed a decrease. The concrete with 60% mill scale replacement exhibited a reduction in compressive strength by 34.5%, flexural strength by 27%, and split tensile strength by 19% compared to the control mix.
- Microstructural studies revealed that the mill scale acted as a filler material in the concrete. It was concluded that mill scale can be effectively used as a partial replacement for sand, up to a weight of 40% of the cement content in the concrete.
- This research provides insights into the utilization of mill scale as a sustainable alternative in concrete production, while highlighting the influence of its replacement on the fresh and hardened properties of the concrete.

Selvaraj S and Vijayaprabha C (2021) This experimental study compares the properties of concrete with partial replacement of fine aggregate using iron scale with conventional concrete. Six different mixes were prepared with varying levels of iron scale replacement: S2 (10%), S3 (20%), S4 (30%), S5 (40%), S6 (50%), and S7 (60%), and compared with conventional concrete (S1). The fresh concrete properties, such as slump cone test, and hardened concrete properties, including compressive strength test for cubes, splitting tensile test for cylinders, and flexural strength test for beams, were evaluated. These properties were compared with those of conventional concrete to determine the optimum level of fine aggregate replacement with iron scale.

P Ganeshprabhu, et al (2020) conducted research to explore the use of steel mill scales, a waste product from the steel production industry, as a partial replacement for sand in construction. Steel mill scale is known to have adverse effects on the environment, but it has shown potential as a substitute for fine aggregates in the construction sector.

- The study focused on the M30 grade concrete and investigated the effects of different percentages of steel mill scale substitution (0%, 20%, 40%, 60%, 80%, and 100%) by weight in comparison to the original M30 grade concrete. The evaluation included the assessment of compressive strength, split tensile strength, flexural strength, and microstructural properties of the concrete.
- Through meticulous microstructural studies, the researchers examined the interaction of steel mill scale within the concrete. They observed that the small particle size of steel mill scale effectively filled the voids between the fine and coarse aggregates, resulting in denser concrete. The test outcomes indicated that recycling steel mill scale as a partial replacement for fine aggregate, particularly at a 60% substitution level, offered a viable, cost-effective, and environmentally friendly solution.
- This research suggests that incorporating steel mill scale into concrete can contribute to waste reduction and environmental sustainability while maintaining the desired strength characteristics of the concrete mixture.

Dana - Adriana Iluțiu et al (2020) aimed to evaluate the recycling potential of mill scale in mortar composition to enhance the management of industrial waste from steelmaking in electric arc furnaces and identify solutions for natural resource conservation. The study involved replacing sand in mortar compositions with varying proportions of mill scale. The researchers presented experimental procedures to characterize the physical and mechanical properties of the mortars. The results showed that substituting sand with mill scale led to reduced compressive strength and flexural strength compared to the standard sample. As the proportion of mill scale increased, the mechanical strengths of the samples decreased below the value of the standard sample.

Arpit Chatter & Dr. J.N. Vyas (2020) Concrete is a highly versatile construction material widely used across the world. However, the extraction and processing of natural aggregates, a major component of concrete, have significant environmental impacts. In order to address this issue, efforts are being made to explore suitable recycled materials as substitutes for aggregates, such as recycled concrete aggregate, post-consumer glass, and fiber materials. However, one waste material that has received limited attention is mill scale, a magnetic material consisting of iron that is formed in steel manufacturing factories.

- This paper focuses on the usage of mill scale as a partial replacement for natural fine aggregates in Portland cement concrete. The addition of mill scale leads to changes in the properties of the concrete. To evaluate these changes, concrete of M20 grade is prepared with varying percentages of mill scale content in the fine aggregate, ranging from 0% to 50%. The compressive, tensile, and flexural strengths of the concrete cubes are determined, while maintaining a constant water-to-cement ratio of 0.5 for all mix proportions.
- The compressive strength of the concrete cubes is determined using a compression testing machine. Tensile strength is indirectly measured through a splitting tensile test using a universal testing machine (UTM), and flexural strength is determined using a two-point loading test. The results are compared for different mill scale content, and the optimum mill scale content that yields the highest strength value is identified.
- By examining the effects of mill scale content on the concrete's strength properties, this study aims to provide insights into its potential as a viable replacement material in concrete production.

Eelaprolu BajiBabu, et al (2018) highlighted the crucial role of concrete in construction and the significant environmental impact caused by the excavation and processing of natural materials for concrete production. Various experiments have been conducted to explore substitutes for concrete aggregates, including recycled concrete aggregate, tile waste, glass waste, tires, metakaolin, brick waste, and fly ash. However, one waste material that has not been extensively studied is mill scale, a hazardous solid waste with a flaky texture that forms on the surface of steel during manufacturing processes.

- In addition to mill scale, another readily available and cost-effective material is rice husk ash. Both mill scale and rice husk ash have the potential to be utilized as sustainable alternatives in concrete production. Their properties and performance as concrete constituents have not been widely explored yet.
- Further research and experimentation are necessary to assess the feasibility and effectiveness of incorporating mill scale and rice husk ash into concrete mixtures. By investigating these alternative materials, it is possible to find innovative and environmentally friendly solutions that can reduce the reliance on natural resources and minimize the environmental impact associated with concrete production.

P.M. Rameswaram et al (2018) During the steel production process, various waste products are generated, and while some of these wastes are reused through refining processes within the steel industry, there are certain materials that become unusable even after refinement due to significant changes in their chemical composition and physical properties. Steel mill scale is one such waste product of the steel industry. It primarily consists of iron and has the potential to be utilized in the field of civil engineering for various purposes.

- Many cement industries have already been using steel mill scale to produce different types of Portland cement, primarily due to its iron content. As a result, this material possesses properties similar to fine aggregate. To determine the potential properties of steel mill scale, several basic tests have been conducted, and the test results indicate that it can be employed as a partial replacement for fine aggregate in concrete production.
- By incorporating steel mill scale as a partial replacement for fine aggregate in concrete, the construction industry can make efficient use of this waste material. This not only helps in reducing the environmental impact of waste disposal but also contributes to sustainable construction practices.

Radhu Chandini (2017) addresses the pressing concern of industrial waste slag, particularly steel slag, and its impact on the environment. Steel slag is a byproduct generated in large quantities during steel manufacturing processes, including Electric Arc Furnaces (EAF) and Basic Oxygen Furnaces (BOF), which smelt iron ore. While steel slag has multiple applications in the construction industry, such as in asphalt surface applications, Stone Matrix Asphalt (SMA), berms and embankments, and even in the production of Portland cement, its disposal can have negative environmental consequences.

- To mitigate these environmental issues, there is a need to explore various applications of steel slag. One promising area is its use as a replacement for natural aggregates, both coarse and fine, in conventional concrete mixtures. Since aggregates constitute a significant volume of concrete, substituting some or all of the natural aggregates with steel slag can yield substantial environmental benefits. This report highlights significant studies conducted on the use of steel slag as a fine aggregate and its impact on the resulting mix's strength, durability, fresh density, workability, and other properties. The report also discusses the current properties and applications of steel slag in the industry.

Jing Ming et. Al (2017) conducted a study to examine the corrosion performance of reinforcing steels in concrete when exposed to a 3.5 wt% NaCl solution for a period of 4 years. The study focused on two types of steels: low-carbon (LC) steel and low-alloy (LA) steel with a chromium alloying element. For each type of steel, two surface conditions were considered: one with the as-received surface (including mill scale) and the other with a pickled surface (mill scale removed).

- The researchers analyzed the microstructure of the steel-concrete interface to investigate how the type of steel and surface condition influenced the corrosion pattern. The results indicated that the corrosion resistance and corrosion pattern of the steels were significantly affected by the characteristics of the mill scale present on the steel surfaces.
- This study highlights the importance of considering the presence of mill scale when evaluating the corrosion behavior of reinforcing steels in concrete. The findings suggest that the mill scale on the steel surfaces plays a significant role in the corrosion process and should be taken into account when assessing the long-term durability and performance of reinforced concrete structures.

Anupam Singhal et. al (2015) conducted a study to explore the potential of mill scale as a substitute for natural fine aggregates in Portland cement concrete. While various recycled materials like recycled concrete aggregate, post-consumer glass, and tires have gained importance as concrete substitutes, mill scale remains relatively untested. Mill scale is a hazardous solid waste with a flaky texture that forms on the surface of steel during the steel manufacturing process.

- The study involved preparing cement mortars with a mix proportion of 1:3, varying the mill scale content of the fine aggregate from 0% to 100%. The water-to-cement ratio was fixed at 0.5 for all mix proportions. The compressive and tensile strength of the concrete samples were determined. Interestingly, the compressive strength did not follow a consistent trend, and two peaks were observed at 60% replacement and 100% replacement of the standard sand. The maximum tensile strength was observed at a 60% replacement level of standard sand.
- In addition, a mix design was conducted for M35 grade concrete using the IS method. OPC of 43 grade was selected, and the sand was replaced with mill scale ranging from 0% to 80% with a suitable water-to-cement ratio of 0.40. The compressive strength was measured after a curing period of 28 days. The maximum strength was achieved when the sand was replaced with 40% mill scale.
- It should be noted that concrete containing mill scale required a higher water content to maintain workability compared to traditional concrete mixes.

Jing Ming and Jinjie Shi (2014) conducted a study to investigate the corrosion products at the steel-concrete interface for a chromium-bearing low-alloy (LA) steel and a conventional low-carbon (LC) steel, both with intact mill scale. The researchers utilized backscattered electron (BSE) images to examine the distribution and penetration of corrosion products.

- The study also compared the effects of mill scale properties and different corrosion inducing methods, including long-term exposure to chloride solution and accelerated corrosion by chloride electromigration. The results revealed complex interactions between the corrosion products and the mill scale of both LC and LA steels at the steel-concrete interface. Moreover, different corrosion patterns were observed for the two types of steels when subjected to different corrosion inducing methods.
- This study provides valuable insights into the relationship between mill scale, corrosion products, and the corrosion behavior of LC and LA steels in the presence of concrete. The findings contribute to a better understanding of the mechanisms involved in the corrosion process and can aid in the development of strategies to enhance the durability and performance of reinforced concrete structures.

Mohammed Nadeem, Arun D. Pofale (2012) This paper presents the results of an experimental investigation on the effects of replacing aggregates (coarse and fine) with slag (crystallized and granular), an industrial waste by-product, on concrete strength properties.

The study employed Taguchi's optimization approach and was conducted in three phases. The results showed that replacing normal crushed coarse aggregate with crystallized slag coarse aggregate improved compressive strength by 5% to 7%. Notable improvements in strength were observed when replacing fine aggregate and both aggregates with slag at 30% to 50% replacement levels. The study also found that full substitution of slag aggregate with normal crushed coarse aggregate improved flexural and split tensile strength by 6% to 8%. Overall, the Taguchi approach helped identify the factors influencing the outcomes, and it was recommended that slag be effectively utilized as coarse and fine aggregates in concrete applications.

Viktors Mironovs et al (2011) The rational utilization of highly dispersed metal waste is a significant concern in material science and environmental protection. The usage of powdered metallic materials in various industries is steadily increasing, with wide applications in the production of iron powders, metal sheets, and abrasive machining. This paper analyzes different types of metal waste, including iron and steel powders, mill scales, steel punching, metal shavings, and other iron-containing waste from mechanical engineering and metallurgy industries. It explores the potential of utilizing these wastes as fillers in the manufacturing of concrete products.

- The study investigates the properties of concrete samples manufactured using highly dispersed metallic fillers. The obtained concrete samples exhibit a density range of 4000 - 4500 kg/m<sup>3</sup>. These materials share common characteristics such as low cost, availability, potential for large-scale production, the need for recycling, and susceptibility to oxidation and corrosion.
- Overall, this research highlights the potential of using highly dispersed metal waste as fillers in concrete production. This approach offers economic and environmental benefits by utilizing waste materials and reducing the demand for traditional fillers.

### III. RESEARCH GAP

#### A. *Optimal Replacement Levels*

- 1) Lack of consensus on the ideal percentage of steel mill scale replacement for fine aggregates in concrete.
- 2) Further research needed to determine the most suitable replacement level to achieve desired concrete properties.

#### B. *Workability Considerations*

- 1) Limited information on the influence of mix designs, water-to-cement ratios, and admixtures on the workability of concrete containing steel mill scale.
- 2) Investigation required to optimize mix proportions and incorporate admixtures to enhance workability.

#### C. *Long-Term Durability*

- 1) Insufficient data on the long-term performance of concrete with steel mill scale, including resistance to corrosion, sulfate attack, and carbonation.
- 2) Understanding the long-term behavior is crucial for assessing the suitability and sustainability of using steel mill scale in concrete.

#### D. *Environmental Impact Assessment*

- 1) Need for life cycle assessments and carbon footprint analyses to evaluate the overall environmental implications of incorporating steel mill scale in concrete.
- 2) Comparison with conventional concrete production is necessary to assess the environmental benefits.

Addressing these research gaps will enhance the knowledge and understanding of the optimal utilization of steel mill scale and other industrial waste materials in concrete, leading to more sustainable construction practices.

### IV. CONCLUSION

The expected outcome of this study is to provide valuable insights into the engineering behavior of sustainable concrete incorporating steel mill scale as a fine aggregate replacement, with a particular focus on the effect of acid admixture on improving workability. The study aims to achieve the following outcomes:

- 1) *Improved Workability*: It is anticipated that the addition of the admixture to the concrete mix will enhance the workability by reducing the water demand and improving the flowability. This is expected to facilitate the placement and compaction processes, making the concrete easier to handle and ensuring uniform distribution within the formwork.
- 2) *Enhanced Fresh Properties*: The study expects to observe improved fresh properties of the concrete, such as increased slump, better cohesiveness, and reduced segregation. These improvements will indicate that the concrete incorporating steel mill scale and the admixture can maintain its desired consistency and homogeneity during the construction process.
- 3) *Optimal Strength Development*: It is anticipated that the hardened concrete samples will exhibit comparable or even higher compressive strength compared to conventional concrete mixes. The pozzolanic activity of steel mill scale, combined with the effectiveness of the admixture, is expected to contribute to the development of strong and durable concrete.
- 4) *Enhanced Durability*: The study aims to assess the durability performance of the concrete, including resistance to chloride ingress, carbonation, and sulfate attack. It is expected that the use of steel mill scale as a fine aggregate replacement, along with the admixture, will improve the concrete's durability properties, leading to increased service life and reduced maintenance needs.
- 5) *Environmental Benefits*: The research seeks to highlight the environmental benefits of using steel mill scale as a sustainable alternative to conventional fine aggregates. The expected outcome is to demonstrate the potential for reducing waste generation from the steel industry while conserving natural resources and minimizing the carbon footprint associated with concrete production.

Overall, the expected outcome of this study is to provide evidence supporting the feasibility and effectiveness of using steel mill scale and the admixture to produce sustainable concrete with improved workability. The findings will contribute to the development of more sustainable construction practices and provide guidance for engineers and practitioners in utilizing waste materials and optimizing concrete mix designs for enhanced performance and reduced environmental impact.



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