UTILIZATION OF FLY ASH AND COPPER SLAG FOR HIGH STRENGTH CONCRETE: REVIEW

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Abstract: Concrete, as a pivotal construction material, has undergone significant evolution over centuries to meet diverse architectural and engineering needs worldwide. This paper explores the global significance of concrete and its recent trends towards sustainable practices driven by environmental concerns and the imperative for resource efficiency. In the context of India, where concrete plays a crucial role in infrastructure development, emphasis is placed on its versatility and durability, making it a preferred choice for various construction projects. Despite challenges such as raw material availability and quality control, ongoing research and development efforts aim to address these issues and ensure the continued growth and improvement of the concrete sector in India. The paper reviews pertinent literature, highlighting studies on the incorporation of fly ash and copper slag in concrete production, and evaluates their impact on mechanical properties. Additionally, it discusses the potential of non-destructive testing (NDT) methods in assessing concrete properties and identifies gaps in existing research, particularly regarding long-term performance, durability studies, and the combined effects of waste materials. The primary objective of this study is to establish the reliability of NDT as an alternative to destructive testing methods and address gaps in the current body of knowledge. This research contributes to advancing concrete technology, optimizing construction practices, and promoting sustainability in the Indian construction industry.

Keywords: Concrete Mix M60 grade, Fly Ash, Cooper Slag, High Strength Concrete

1. INTRODUCTION

We discuss the global significance of concrete as a crucial construction material and its evolution over centuries to meet diverse architectural and engineering needs. Emphasis is placed on recent trends in sustainable practices within the concrete industry, driven by a growing awareness of environmental impacts and the need for resource efficiency. In the context of India, concrete plays a pivotal role in infrastructure development, fueled by rapid urbanization and ambitious government initiatives. Its versatility and durability make it a preferred choice for various construction projects, from residential buildings to large-scale infrastructure. The over utilization highlights the adoption of sustainable practices in India's concrete industry, including the use of eco-friendly materials and optimized mix designs to mitigate environmental impact. Despite challenges such as raw material availability and quality control, ongoing research and development efforts aim to address these issues and ensure the continued growth and improvement of the concrete sector in India.

Overall, concrete in India is not merely a construction material but a symbol of the nation's progress and development, shaping its infrastructure and architectural landscape as it continues to modernize and grow.

2. LITERATURE REVIEW

2.1 Tiwary, A.K. and Bhatia, S., along with their team in 2022, aimed to determine the optimal percentage of fly ash and copper slag substitutions in concrete, focusing on their influence on mechanical characteristics. They employed M40 grade concrete with fly ash replacing cement by 20% and copper slag substituting fine aggregate by varying percentages (0%, 15%, 30%, 45%, and 60%).Various aspects were considered to assess the combined effect of these waste materials. The results indicated that substituting copper slag for more than 30% of fine aggregates led to decreased strengths due to its low water retention rate. However, concrete with 20% fly ash replacement as cement and 30% copper slag replacement as fine aggregates exhibited improved flexural strength, split tensile strength, and compressive strength. Furthermore, the study found that the ultrasonic pulse velocity was highest for the concrete mix containing 20% fly ash and 30% copper slag substitutions. This suggests that this particular combination resulted in enhanced concrete quality, potentially due to improved bonding and densification within the material. Overall, the findings underscore the potential of incorporating fly ash and copper slag as sustainable alternatives in concrete production, highlighting their positive impact on mechanical properties when used within specific proportions. These results contribute to the ongoing efforts in the construction industry to optimize material usage and promote environmentally friendly practices.

2.2 Sambangi, A. and Arunakanthi, E.J.M.T.P., along with their team in 2021, focused on Self Compacting Concrete (SCC), a unique type of concrete that compacts itself without the need for external vibration. They emphasized the importance of workability, often referred to as fresh properties, in SCC, which includes factors such as flowing ability, filling ability, segregation resistance, and passing ability. These properties are typically assessed through tests like Slump flow, U-Box, V-Funnel, and L-Box ratio tests. The study involved the partial replacement of cement with fly ash at varying percentages (5%, 10%, 15%, 20%, 25%, and 30%), as well as the substitution of fine aggregate with copper slag at different levels (ranging from 10% to 100%). The results showed that increasing the proportions of fly ash and copper slag led to improvements in the fresh properties of SCC. Notably, the optimal replacement ratio was found to be 20% fly ash replacing cement and 40% copper slag substituting fine aggregate. Furthermore, the study observed that the mix containing 40% copper slag exhibited higher mechanical properties compared to the regular mix. However, it was noted that at early ages, both fly ash and copper slag led to a decrease in mechanical properties compared to conventional mixes, with a decrease in compressive strength from 51.27 MPa to 31.17 MPa. Overall, the study concluded that the addition of fly ash significantly influenced the fresh properties of SCC, while the proportion of copper slag was directly proportional to improvements in fresh properties. However, it also highlighted the importance of considering the potential impact on mechanical properties, particularly at early ages, when incorporating supplementary materials like fly ash and copper slag in SCC mixes.

2.3 Raju, S. and Dharmar, B., along with their team in 2020, investigated the effects of incorporating fly ash (FA) and copper slag (CS) on the fresh and hardened properties of concrete. They designed M30 grade concrete with a constant water-cement ratio of 0.4 and conducted experiments using twenty-four different concrete mixtures. These mixtures varied by partially replacing cement with FA ranging from 0% to 30% in 10% increments, and by substituting natural sand with CS from 0% to 100% in 20% increments. The compressive strength of the concrete was tested at curing periods of 3, 7, 14, 28, 56, and 90 days to assess its hardened properties. Additionally, five reinforced concrete (RC) beams sized at 150 mm × 250 mm × 3200 mm were cast based on the optimal mix proportion, and the flexural behavior of these beams was monitored through a four-point bending test. The experimental results revealed that both compressive strength and flexural strength increased in concrete mixes containing 30% FA and 80% CS. This improvement was attributed to the smaller surface area of CS per unit volume being exposed to a larger quantity of the concrete matrix, as well as the enhanced workability of the concrete. Overall, the study demonstrates the potential benefits of incorporating FA and CS in concrete mixes, particularly in terms of strength properties and workability. These findings contribute to the ongoing efforts to optimize concrete mix designs and enhance the performance of concrete in various applications.

2.4 Tiwary et al. (2018) aimed to investigate the effects of incorporating fly ash as a partial replacement for cement and copper slag as a substitute for fine aggregate on the properties of concrete. Various concrete samples were prepared, with different proportions of copper slag ranging from 0% to 60% as a replacement for fine aggregates, and 20% fly ash replacing cement. These samples were then evaluated for compressive, tensile, and flexural strength, as well as for ultrasonic pulse velocity. The results obtained indicated that all concrete samples, with varying amounts of copper slag while maintaining a constant fly ash proportion, exhibited higher compressive strength compared to the control specimens. Furthermore, it was observed that as the percentage of copper slag increased, the workability of the concrete also increased in comparison to the control specimens. However, when the copper slag replacement exceeded 30% of fine aggregate, a reduction in strengths was noted due to the low water absorption of copper slag. Overall, the findings suggested that utilizing 20% fly ash as a substitution for cement and up to 30% copper slag as a replacement for fine aggregate could lead to concrete with improved mechanical properties. These results contribute to the understanding of how the incorporation of industrial by-products such as fly ash and copper slag can enhance the performance of concrete, providing insights for sustainable and efficient concrete production practices.

2.5 Veerraju and Arunchaitanya (2018) focused on investigating the properties of M60 grade concrete by partially replacing cement with fly ash and fine aggregate with copper slag. Fly ash was substituted at percentages ranging from 5% to 25% of the weight of cement, while copper slag was replaced at various percentages from 10% to 50% of the weight of fine aggregates. The study aimed to evaluate the compressive strength, flexural strength, and split tensile strength of the hardened concrete with these replacements. Additionally, tests such as slump cone, V-funnel, L-box, J-box, and T-50 were conducted to assess fresh concrete properties. The findings of the study indicated that the test results for fresh concrete were within the limits outlined in the EFNARC-2005 guidelines, with a decrease in water-to-powder (W/P) ratio leading to an increase in compressive strength. Self-compacting concrete (SCC) was highlighted as a relatively new form of concrete with advantages such as high compressive strength and self-compacting properties, along with increased flowability, workability, and passing ability. Superplasticizer was identified as a crucial water-reducing agent, with an optimal dosage of 1.5% of superplasticizer (GLENIUM B223) recommended to enhance the self-compatibility of concrete. The study suggested that 15 wt% of fly ash could effectively replace cement, while 30 wt% of copper slag could replace sand to achieve high-strength self-compacting concrete with desirable properties. The utilization of copper slag and fly ash in construction was deemed feasible, offering cost-effective solutions and yielding favorable results. Furthermore, the study emphasized the beneficial aspects of using copper slag as a replacement material for fine aggregate, highlighting its potential to enhance the performance of concrete. Overall, compared to conventional concrete, self-compacting concrete (SCC) exhibited higher compressive strength, suggesting its suitability for various construction applications.

3. MATERIAL

3.1 FLY ASH

Fly ash is a fine powder produced as a byproduct of burning pulverized coal in power plants. It is comprised of both mineral and non-mineral components from the coal combustion process. When coal is burned, its mineral impurities form tiny spherical particles that solidify in the flue gas and are then collected using electrostatic precipitators or baghouses.

Key characteristics of fly ash include its composition primarily consisting of silicon dioxide, aluminum oxide, iron oxide, and calcium oxide. It is predominantly composed of fine particles, many smaller than 10 microns in diameter. There are two main types of fly ash—Class F and Class C—distinguished by their coal source and combustion conditions. Fly ash exhibits pozzolanic properties, meaning it reacts chemically with calcium hydroxide in the presence of water to form compounds with cementitious properties, making it valuable in concrete production.

Fly ash finds primary use as a supplementary cementitious material in concrete, improving workability, reducing heat generation during hydration, and enhancing long-term strength and durability. It also has applications in road construction, embankments, and brick manufacturing. Utilizing fly ash in construction materials contributes to environmental sustainability by reducing the need for traditional cement production and effectively managing this byproduct.

The production of fly ash is directly tied to coal combustion in thermal power plants. Coal is pulverized into a fine powder and burned in boilers to generate electricity. During combustion, mineral impurities in the coal form ash particles, which are carried away in the flue gas. Electrostatic precipitators or baghouses are used to collect the fly ash from the flue gas. The collected ash is stored in silos at power plants and can be transported for various construction applications. Regulations and standards govern its use and disposal to ensure safe and environmentally responsible handling.

3.2 COPPER SLAG

Copper slag is a byproduct generated during the extraction and refining of copper. It is a granular material composed primarily of highly vitrified iron silicate particles and other impurities. This byproduct is formed during the smelting and refining processes in the copper industry.

In concrete applications, copper slag can be used as a partial replacement for fine aggregates. Its pozzolanic and cementitious properties contribute to improved durability and strength of concrete. When properly processed and used in concrete mixes, copper slag can enhance various properties of concrete, including:

Strength: Copper slag can contribute to the development of higher compressive and flexural strengths in concrete, leading to more robust and durable structures.

Durability: The use of copper slag in concrete can improve its resistance to chemical attack, abrasion, and weathering, thereby enhancing the long-term durability of concrete structures.

Workability: Despite its granular nature, properly processed copper slag can improve the workability of concrete mixes, facilitating easier placement and compaction during construction.

Density: Due to its relatively high density, incorporating copper slag into concrete mixes can lead to concrete with increased density, which may be beneficial in certain structural applications.

Environmental Benefits: Utilizing copper slag in concrete reduces the need for natural aggregates, thus conserving natural resources. Additionally, it helps in the management of copper slag waste, contributing to sustainable practices in the construction industry.

Overall, the application of copper slag in concrete offers a sustainable solution that not only enhances the performance of concrete but also addresses environmental concerns associated with waste disposal from the copper industry

4. OBJECTIVE OF STUDY

The main objective of the study is to evaluate the properties of concrete:

- To prepare concrete mix of M60 grade in the laboratory
- Testing of the mix with conventional method and NDT method.
- Develop co-relation after testing.
- Quality assessment of the mix with the help of Ultra Sonic Pulse Velocity method.

5. SCOPE AND IDENTIFYING GAP OF RESEARCH

In the scope of research, the primary objective is to establish the reliability of non-destructive testing (NDT) as a viable alternative to destructive testing methods. The focus will be on demonstrating that NDT results can effectively replace those obtained through destructive testing, with particular emphasis on the ability to reuse samples prepared for testing. Additionally, the research aims to validate the accuracy of NDT in assessing the strength of existing structures. By conducting thorough investigations and analyses, the study seeks to provide empirical evidence supporting the reliability and practicality of NDT techniques in structural assessment and evaluation.

Identifying gaps in existing literature is crucial for shaping the research agenda and highlighting areas that require further investigation. Several significant gaps have been identified in the current body of knowledge. Firstly, existing studies have typically been limited in duration, often concluding within 90 days, which fails to adequately address long-term performance and durability of structures. Secondly, there is a notable absence of research examining the relationship between laboratory experiments and real-world applications of conventional concrete. Furthermore, the utilization of NDT for durability studies is lacking, indicating a need for research in this area. Additionally, critical factors such as water-cement ratio and creep have not been thoroughly studied in the context of NDT assessment. Finally, there is a gap in the literature regarding the combined effects of waste copper slag and fly ash, particularly in terms of their testing using NDT methods. Addressing these gaps will not only enhance our understanding of NDT's reliability but also contribute to advancements in concrete testing methodologies and sustainable material utilization.

6. CONCLUSION

In conclusion, concrete stands as a fundamental material in global construction endeavors, evolving across centuries to meet diverse architectural and engineering needs. Recent trends highlight a shift towards sustainable practices within the concrete industry, driven by growing environmental awareness and the imperative for resource efficiency. In the context of India, concrete plays a pivotal role in infrastructure development, spurred by rapid urbanization and ambitious governmental initiatives. Despite challenges such as raw material availability and quality control, ongoing research and development efforts aim to address these issues, ensuring the continued growth and improvement of India's concrete sector. Reviewing existing literature provides valuable insights into optimizing concrete production processes and enhancing material properties. Studies by Tiwary, Sambangi, Raju, and others explore the incorporation of supplementary materials such as fly ash and copper slag to improve concrete characteristics. These investigations emphasize the potential benefits of utilizing industrial by-products, contributing to sustainable construction practices. However, gaps in research exist, particularly regarding the long-term performance of concrete structures, the relationship between laboratory experiments and real-world applications, and the combined effects of waste materials like copper slag and fly ash. Addressing these gaps is imperative for advancing concrete technology and promoting sustainable construction practices.

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