Green Self Compacting Concrete with Partial Replacement of Aggregates by Slag

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Abstract

As the global construction industry continues to grow, there is an increasing demand for environmentally sustainable building materials. Concrete, being one of the most widely used construction materials, plays a crucial role in shaping the environmental impact of infrastructure projects. This research explores the development and performance of Green Self-Compacting Concrete (GSCC) by incorporating slag as a partial replacement for traditional aggregates.

Introduction

The traditional formulation of concrete, consisting of coarse material (sand) and a mixture of gravel or stones of different shapes and sizes, has been the prevailing norm in building for an extended period. Nevertheless, there is a discernible change in enthusiasm in investigating alternate aggregate materials. Contrary to popular belief, study shows that aggregate, which is commonly seen as a passive substance that has no effect on the characteristics of concrete, really has a significant impact. Research has shown that aggregate has a substantial impact on defining many properties of concrete, such as strength, workability, durability, and dimensional stability.

Aggregate typically constitutes a substantial portion, ranging from 70% to 80%, of the concrete volume. Despite its significant volume, it has historically been considered a passive component. Recent findings, however, emphasize its active role in influencing the overall performance of concrete. This realization is particularly crucial as the demand for natural sand remains high, especially in developing areas. In light of environmental concerns, there is a growing realization that choices in construction materials should be guided by ecological considerations.

The global population explosion, from 1.5 billion at the beginning of the 20th century to 6 billion by the end, underscores the rapid urbanization trend. In the early 1900s, only 11% of the population lived in cities. However, by 2001, nearly half of the 6 billion inhabitants resided in and around urban areas. This demographic shift places increased pressure on construction materials, necessitating a reevaluation of traditional practices.

Anticipating the future, there is a substantial projected increase in the need for concrete. Standard concrete generally consists of 8% mixing water, 12% cement, and 80% aggregate by mass. SCC has been created to address the problems presented by contemporary building demands. SCC is specifically engineered to enable optimal compaction and assist the precise placement of concrete in constructions that have densely packed reinforcing and limited space.

Green self-compacting concrete

Green self-compacting concrete (GSCC) stands at the forefront of sustainable construction, representing a paradigm shift in the realm of concrete technology. As the global community increasingly grapples with environmental challenges, the construction industry has recognized the imperative to embrace eco-friendly alternatives. GSCC emerges as a pioneering solution, integrating environmental consciousness with structural efficiency. This revolutionary concrete variant not only addresses the ecological concerns associated with traditional concrete production but also exhibits superior performance characteristics, thanks to the strategic incorporation of slag as a partial replacement for conventional aggregates.

Concrete, being the most widely used construction material globally, has long been criticized for its significant environmental footprint. The conventional production process involves the extraction of raw materials, notably aggregates, and the energy-intensive cement manufacturing process, contributing to substantial carbon emissions. The quest for sustainable alternatives has led researchers and engineers to explore innovative materials and methodologies, and GSCC has emerged as a beacon of promise.

At its core, self-compacting concrete (SCC) represents a significant advancement in concrete technology. Unlike conventional concrete, SCC possesses the ability to flow and fill the formwork under its own weight without the need for external vibration. This characteristic not only enhances construction efficiency but also facilitates the creation of intricate and complex structures. However, the ecological implications of SCC, despite its technical advancements, have remained a cause for concern.

Enter the concept of "green" in concrete technology — an umbrella term encompassing various approaches aimed at minimizing environmental impact. GSCC, as a subset of green concrete, strives to mitigate the environmental repercussions associated with conventional SCC. One of its key distinguishing features lies in the partial replacement of traditional aggregates with slag, a byproduct of the iron and steel industry. This integration not only addresses the issues of resource depletion but also tackles the problem of managing industrial waste.

Slag is a granular substance that is produced when metals are smelted or refined. It has a high concentration of silica and alumina. GSCC effectively decreases the need for natural resources and takes use of the pozzolanic characteristics of slag by using it as a substitute for some of the aggregates. Pozzolanic materials, when combined more cementitious compounds, with calcium hydroxide in the presence of moisture, hence enhancing the overall durability and robustness of the concrete. The utilization of an industrial waste to enhance concrete qualities demonstrates the mutually beneficial link between sustainability and performance in GSCC.

GSCC has environmental benefits that go beyond simply reducing the usage of raw materials. The manufacturing process of conventional Portland cement, which is a fundamental ingredient in concrete, significantly contributes to the release of carbon dioxide into the atmosphere. On the other hand, GSCC usually includes additional cementitious materials such as slag, which have a reduced environmental impact in terms of carbon emissions. This substitution not only reduces the emission of greenhouse gases but also adds to the overall decrease in the amount of energy contained in the concrete mix.

Methodology

The utilization of slag aggregates in the construction industry is imperative, given their status as an inevitable by-product of the steel and iron manufacturing process. This study focuses on the development of innovative green Self-Compacting Concrete (SCC) by strategically replacing conventional concrete ingredients with slag. The primary aim is to enhance sustainability in construction practices.

The approach utilized in this study is substituting some elements of traditional concrete, fine aggregates, coarse aggregates, with slag and cement. The emphasis on the absolute volume technique of mix design guarantees a methodical approach. The paste volume is adjusted within the range of 0.35 to 0.41 in order to improve the SCC trial mixes.

The study investigates the effects of various combinations of water content (180kg/m^3 and 190kg/m^3) and cement content (300kg/m^3, 375kg/m^3, and 450kg/m^3) on the characteristics of the resultant Self-Compacting Concrete (SCC). For each scenario, coarse aggregates and slag fine are used to substitute conventional aggregates in different ratios, ranging from 0% to 100%.

The research evaluates the fundamental fresh characteristics of the formulated SCC mixes, verifying that the material complies with the required criteria for workability and uniformity. Compressive strength tests are performed on 100mm cubes after 7, 14, and 28 days to assess the long-term effectiveness of the SCC under various curing periods. This analysis offers significant knowledge on the durability and ability to support weight of the ground breaking concrete.

Durability is a crucial aspect of any construction material. To assess this, the study incorporates a sorptivity test, which measures the ability of the SCC to resist water absorption. Accelerated curing is also implemented to simulate and evaluate the performance of the SCC under conditions that expedite the aging process.

Result

Focusing on the w/c ratio and the substitution of slag particles for natural aggregates, this research examines how various parameters affect the compressive strength of concrete. Our next step is to have a look at the essentials:

Effect of w/c Ratio:

The correlation between a reduction in the water-to-cement (w/c) ratio and an augmentation in compressive strength is consistent with the prevailing comprehension of concrete mix design. A reduced water-to-cement ratio often leads to a more compact and robust concrete structure.

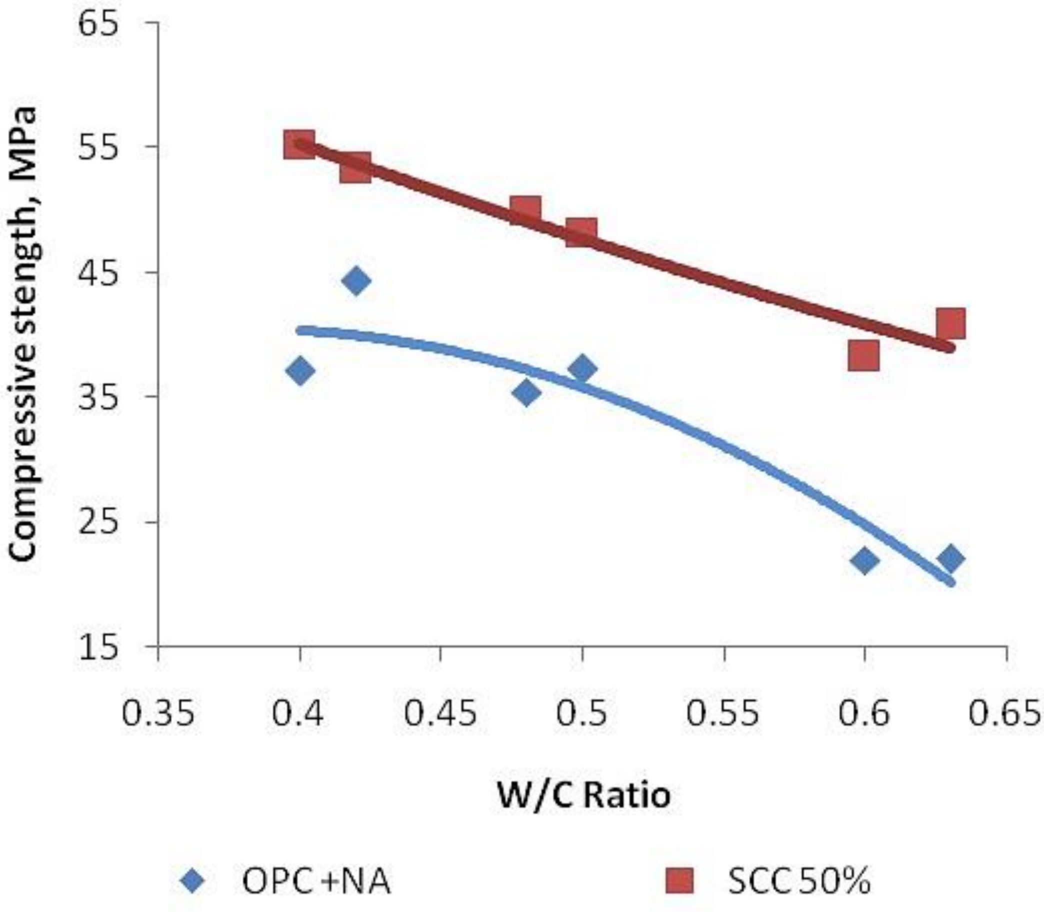
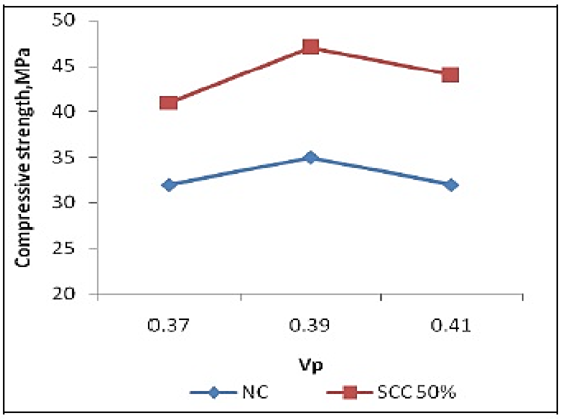


Figure 1. Effect of w/c Ratio

Enhancing Compressive Strength through the Incorporation of Slag Aggregates:

The preliminary analysis reveals that when fine and coarse slag particles are introduced, the compressive strength of the material improves up to a maximum replacement of 50%. Once surpassing this limit, there is a decrease in intensity. This suggests that whereas slag aggregates initially improve strength, there may be a decrease in the benefits or negative consequences when greater replacement percentages are used.



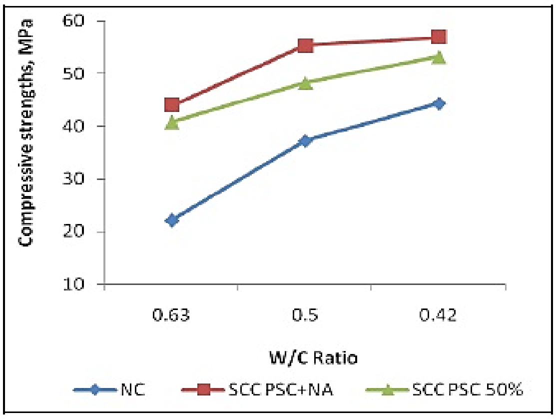


Figure 2. Compressive Strength vs. Vp **Figure 3. Compressive Strength vs. w/c**

Comparison of SCC with Natural Aggregates and PSC:

Self-Compacting Concrete (SCC) with natural aggregates exhibits a 30% increase in strength compared to Normal Concrete (NC). Furthermore, the use of Portland Slag Cement (PSC) in the production of Self-Consolidating Concrete (SCC) results in a noteworthy enhancement, providing a 25% augmentation in compressive strength in comparison to traditional concrete. This indicates the advantageous influence of both pre-stressed concrete (PSC) and self-consolidating concrete (SCC) on the strength of concrete.

Comparison of SCC with Slag Aggregates to Natural Aggregates:

When half of the natural fine and coarse aggregates are replaced by slag aggregates in SCC, there is a 9% decrease in strength compared to SCC that only contains natural aggregates. However, when comparing this self-compacting concrete (SCC) with slag replacement to standard concrete, there is a notable 22% increase in strength. This implies that while there is a reduction in strength when slag is utilized as a replacement in self-compacting concrete (SCC), the total effectiveness is still superior to that of conventional concrete.

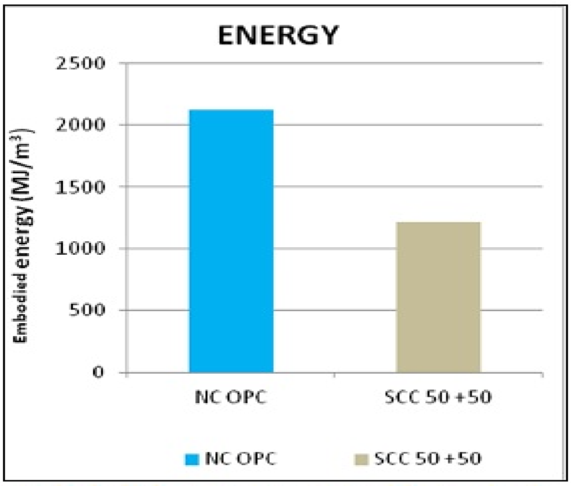


Figure 4. A Comparative Analysis of Energy Efficiency in Traditional Concrete (OPC) versus Self-Consolidating Concrete (SCC) with 50% Portland Slag Cement (PSC) Replacement

Conclusion

The compressive strength of SCC surpasses that of Normal Concrete (NC) at a consistent w/c ratio, emphasizing its superior performance. Notably, the use of slag aggregates and slag cement in SCC results in a substantial 30 percent increase in compressive strength compared to conventional concrete, showcasing the efficacy of slag as a sustainable alternative to natural aggregates. Moreover, SCC formulated with marginal materials not only outperforms traditional concrete while maintaining the same parameters but is also cost-effective and energy-saving. This dual advantage makes SCC a promising solution, contributing to enhanced strength, reduced environmental impact, and increased sustainability in modern construction practices.

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