SELF COMPACTING CONCRETE USING INDUSTRAILWASTE MATERIALS

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Abstract
The popularity of self-compacting concrete (SCC) has skyrocketed in recent years, and a lot of work has gone into perfecting the formula so that it has the necessary properties. The incorrect disposal of waste foundry sand produced by metal casting businesses is a major source of environmental damage. The use of foundry sand in self-compacting concrete is a hot topic in the field right now. This experiment showcases the feasibility of partially substituting waste foundry sand for fine aggregate in self-compacting concrete. Experiments are conducted on M35 grade self-compacting concrete containing varying percentages of waste foundry sand (0%, 10%, 20%, 30%, 40% by weight). Produced material was evaluated for strength and compared to standard self-compacting concrete. In order to ascertain the mechanical characteristics of self-compacting concrete, standard cube, cylinder, and beam tests are conducted for 7 and 28 days. The purpose of this study is to determine the effect that varying percentages of industrial waste have on the behavior and mechanical characteristics of self-compacting concrete via the use of tests such as compressive strength, split tensile strength, and flexural strength. The study may be used as a reference for looking at foundry sand as a possible replacement for natural resources.

Keywords: Self-Compacting Concrete (SCC), Industrial waste materials, Supplementary cementitious materials (SCMs), Fly ash, Ground granulated blast furnace slag (GGBFS), Silica fume, Rice husk ash, Metakaolin, Industrial by-products, Waste materials in concrete, Sustainable construction materials, Green concrete, Waste utilization in construction, Environmental impact of concrete, Waste-to-resource approach, High-performance concrete, Rheology of SCC.

I. INTRODUCTION

Self-compacting concrete (SCC) has gained significant attention in the construction industry due to its exceptional flowability and ability to fill intricate formwork without the need for mechanical compaction. It offers numerous advantages, including improved construction efficiency, enhanced durability, and reduced labor costs. Additionally, incorporating industrial waste materials into SCC not only addresses the issue of waste disposal but also contributes to sustainable construction practices by reducing the reliance on traditional raw materials

Industrial waste materials, generated from various manufacturing processes, pose a significant environmental challenge. However, they can be effectively utilized as alternative materials in SCC production, leading to waste reduction and minimizing the environmental impact associated with their disposal. The incorporation of these waste materials not only enhances the properties of SCC but also contributes to the circular economy by converting waste into valuable resources.

There is a wide range of industrial waste materials that have been investigated for their suitability in SCC production. Supplementary cementitious materials (SCMs) such as fly ash, ground granulated blast furnace slag (GGBFS), silica fume, rice husk ash, and metakaolin are commonly used. These materials possess pozzolanic properties and can partially replace cement in SCC mixes, resulting in improved workability, strength, and durability.

The utilization of industrial waste materials in SCC requires careful consideration of their chemical and physical properties, including particle size distribution, specific surface area, and pozzolanic activity. The mix design optimization is crucial to achieve the desired flowability, segregation resistance, and mechanical properties of SCC while incorporating the waste materials.

The use of SCC incorporating industrial waste materials offers multiple benefits. Firstly, it helps reduce the consumption of virgin raw materials, thus conserving natural resources. Secondly, it contributes to waste management and reduces the burden on landfills. Thirdly, the improved workability and flowability of SCC enable efficient construction practices, reducing labor requirements and construction time.

Moreover, SCC incorporating industrial waste materials exhibits comparable or even enhanced mechanical properties compared to conventional concrete. The pozzolanic reactions between the waste materials and cement contribute to the development of a denser microstructure, resulting in increased strength, improved durability, and reduced permeability.

In conclusion, the incorporation of industrial waste materials in self-compacting concrete represents a sustainable approach towards construction. By utilizing these waste materials, it is possible to achieve a high-performance concrete with improved workability, strength, and durability while simultaneously addressing the environmental challenges associated with waste generation and disposal. This approach aligns with the principles of sustainable development and the circular economy, promoting resource efficiency and waste reduction in the construction industry.

LITERARURE SURVY

[1] Rashad, A. M. (2015). “Utilization of blended waste materials in self-compacting concrete”. This study investigates the use of various waste materials, including fly ash, slag, and limestone powder, in SCC. The effects of these waste materials on the fresh and hardened properties of SCC are examined

Tam, V. W., Gao, X. F., & Tam, C. M. (2007). “Microstructural analysis of sustainable self-compacting concrete incorporating high-volume slag, fly ash and natural pozzolans”. The authors explore the microstructural properties of SCC incorporating high volumes of slag, fly ash, and natural pozzolans. The study evaluates the influence of these waste materials on the mechanical and durability properties of SCC.

[2] Safiuddin, M., West, J. S., & Claisse, P. A. (2013). “Influence of the incorporation of recycled concrete aggregates and supplementary cementitious materials on the properties of fresh and hardened self-compacting concrete”. This research investigates the effects of incorporating recycled concrete aggregates and supplementary cementitious materials, such as fly ash and slag, on the properties of fresh and hardened SCC. The study assesses the workability, compressive strength, and durability characteristics of the concrete.

[3] Begum, S., & Santhanam, M. (2010). “Influence of fly ash and metakaolin combination on self-compacting concrete. The authors examine the combined effects of fly ash and metakaolin on the properties of SCC”. The study investigates the fresh properties, compressive strength, and microstructure of SCC mixtures containing different proportions of fly ash and metakaolin.

[4] Latha, G. M., & Sekar, A. S. S. (2013). “Influence of ground granulated blast furnace slag on self-compacting concrete”. This study explores the influence of ground granulated blast furnace slag (GGBFS) on the properties of SCC. The effects of GGBFS on workability, compressive strength, and durability properties of SCC are examined.

[5] Siddique, R., Kaur, G., & Aggarwal, P. (2015). “Effect of fly ash and silica fume on heat of hydration of self-compacting concrete incorporating ultrafine fly ash”. The authors investigate the effect of incorporating fly ash and silica fume, including ultrafine fly ash, on the heat of hydration of SCC. The study examines the impact of these materials on the hydration characteristics and early-age properties of SCC.

[6] Azad, A. K., Mahmud, H. B., & Muntohar, A. S. (2012). “Influence of rice husk ash on engineering properties of self-compacting concrete”. This research focuses on the influence of rice husk ash (RHA) on the engineering properties of SCC. The study evaluates the fresh properties, compressive strength, and durability of SCC incorporating RHA.

PROBLEM STATEMENT

The construction industry generates a significant amount of industrial waste materials, which often pose environmental challenges in terms of disposal and management. Simultaneously, there is a growing need for sustainable construction practices that reduce the consumption of natural resources and minimize the environmental impact of construction activities. Incorporating industrial waste materials into self-compacting concrete (SCC) presents an opportunity to address both waste management and sustainability concerns.

LIMITATIONS

Variation in Waste Material Characteristics: Industrial waste materials can exhibit significant variations in their physical, chemical, and mineralogical properties, depending on their source and production process. This variability can affect the performance and consistency of SCC incorporating these waste materials, making it challenging to achieve consistent results.

- **Compatibility Issues:** Some industrial waste materials may not be compatible with the other components of SCC, such as cement, aggregates, or chemical admixtures. Incompatibility issues can lead to poor workability, setting time delays, or undesirable chemical reactions, compromising the overall performance of the concrete.
- **Limited Availability and Consistency:** The availability and consistency of industrial waste materials can be a limitation. Some waste materials may not be readily available in sufficient quantities or may have inconsistent supply, making it challenging to use them as a consistent replacement for conventional materials in SCC.
- **Influence on Fresh Properties:** Incorporating industrial waste materials in SCC can have varying effects on the fresh properties, such as workability, flowability, and segregation resistance. The addition of certain waste materials may require adjustments to the mix design or additional admixtures to achieve the desired SCC properties.
- **Impact on Mechanical Strength:** While industrial waste materials can contribute to the strength development of SCC, their influence on mechanical properties may vary. The strength gain may be slower or lower compared to conventional SCC, requiring longer curing periods or higher amounts of waste materials to meet specific strength requirements.
- **Durability Considerations:** The impact of industrial waste materials on the durability properties of SCC may be uncertain. Some waste materials may introduce potential durability issues, such as increased porosity, higher permeability, or susceptibility to chemical reactions, which could affect the long-term performance and durability of SCC structures.
- **Lack of Standardization and Guidelines:** The absence of standardized guidelines and specifications for SCC incorporating specific industrial waste materials can be a limitation. The lack of clear guidance may hinder the widespread adoption of these materials and create uncertainty regarding their performance and acceptance in construction practices.
- **Environmental and Regulatory Considerations:** While incorporating industrial waste materials in SCC can contribute to sustainable practices, there may be environmental and regulatory constraints. Some waste materials may contain hazardous components or require special handling and disposal procedures, which can add complexity and regulatory compliance challenges.

II. METHODOLOGY

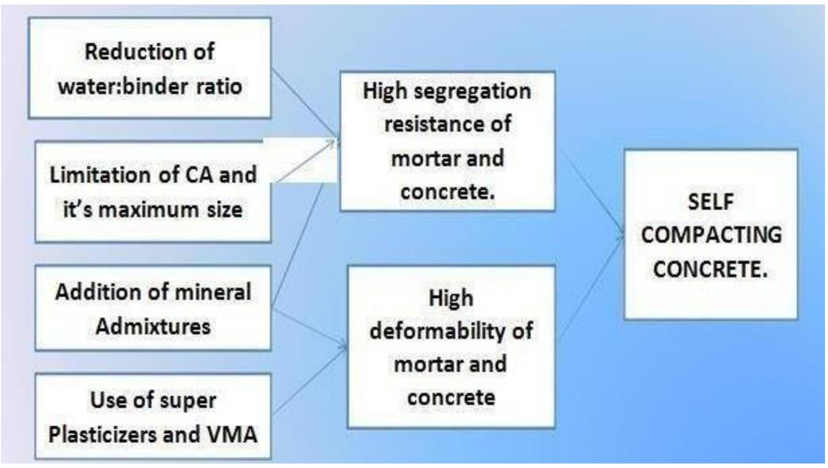


Figure 1: Proposed Mechanism of achieving self compaction.

Self-Compacting Agents: SCC may also include viscosity-modifying admixtures (VMAs) or stabilizers, which further enhance the self-compactability of the concrete. VMAs improve the viscosity and yield stress of the mixture, preventing segregation and enhancing stability. They help the concrete maintain its shape and prevent excessive settlement or bleeding.

Selection of Industrial Waste Materials: Identify and select suitable industrial waste materials based on their availability, characteristics, and compatibility with SCC. Consider waste materials such as fly ash, slag, silica fume, rice husk ash, bottom ash, or other by-products from industries like steel, power plants, and manufacturing.

Characterization of Waste Materials: Conduct a detailed characterization of the selected waste materials to determine their physical, chemical, and mineralogical properties. Perform tests such as particle size analysis, specific gravity, chemical composition, pozzolanic activity, and reactivity to assess their suitability for use in SCC.

Mix Design Optimization: Develop an optimized mix design for SCC incorporating industrial waste materials. Conduct a series of trial mixes with varying proportions of waste materials, cement, aggregates, and water to achieve the desired flowability, stability, and mechanical properties of SCC. Use superplasticizers and viscosity-modifying admixtures, if necessary, to enhance workability and control viscosity.

Fresh Properties Assessment: Evaluate the fresh properties of SCC incorporating waste materials, including slump flow, T50 time (time taken to reach 50 cm spread diameter), and V-funnel flow time. Conduct slump flow tests and V-funnel flow tests to assess the flowability and filling ability of SCC. Measure the passing ability through obstacles, such as L-box or U-box tests, to evaluate the SCC's ability to flow into congested reinforcement areas.

Mechanical Property Testing: Perform mechanical property tests to assess the strength and durability characteristics of SCC with waste materials. Conduct compressive strength tests, flexural strength tests, and split tensile strength tests on hardened SCC specimens. Evaluate the influence of waste materials on the strength development and compare the results with conventional SCC mixes.

Durability Evaluation: Assess the durability performance of SCC with industrial waste materials. Conduct tests such as water absorption, permeability, chloride ion penetration, sulfate resistance, carbonation depth, and alkali-aggregate reaction potential to evaluate the durability properties of SCC. Compare the results with conventional SCC to determine the impact of waste materials on durability.

Microstructural Analysis: Perform microstructural analysis, such as scanning electron microscopy (SEM) and X-ray diffraction (XRD), to examine the hydration products, interfacial transition zone, and the distribution of waste materials in the hardened SCC. Analyze the microstructure to understand the potential interactions between waste materials and the cementitious matrix.

Long-Term Performance Assessment: Conduct long-term performance assessments of SCC incorporating industrial waste materials. Perform accelerated aging tests, such as freeze-thaw cycles, wet-dry cycles, and thermal cycling, to simulate harsh environmental conditions and assess the durability and long-term behavior of SCC.

Environmental Impact Analysis: Evaluate the environmental impact of SCC with waste materials using life cycle assessment (LCA) methodologies. Assess the reduction in carbon emissions, energy consumption, and natural resource conservation achieved by incorporating waste materials into SCC. Compare the environmental impact with conventional concrete mixtures.

Guidelines and Standardization: Develop guidelines and specifications for the use of SCC incorporating specific industrial waste materials. Establish standardized procedures for mix design, testing, and quality control to facilitate the adoption and implementation of SCC with waste materials in construction projects.

SELF COMPACTING CONCRETE

The unique properties of Self-Compacting Concrete (SCC) allow it to compact and flow under its own weight, eliminating the requirement for vibration. It has a high quality surface finish, is very workable, and may be used to fill complicated and crowded formwork. In situations where it would be too time-consuming or difficult to utilize traditional concrete laying techniques, SCC is often used.

Figure 2: Self-Compacting Concrete (SCC)

The key characteristics of SCC include:

High Flowability: SCC exhibits excellent flowability, allowing it to flow freely into the formwork and around reinforcement without the need for mechanical compaction. It can easily pass through congested areas and fill complex shapes.

Self-Compacting Nature: SCC is self-compacting, meaning it can achieve full compaction without the need for external vibration. This property is achieved through a balanced combination of high workability, proper viscosity, and adequate stability.

Segregation Resistance: SCC has excellent resistance to segregation, which means that the coarse aggregates do not separate from the mortar phase during pouring and compaction. This ensures uniform distribution of aggregates and a homogenous mixture.

High Strength and Durability: SCC can achieve the same or even higher strength and durability as conventional concrete. By using appropriate mix design, incorporating suitable admixtures, and ensuring proper curing, SCC can meet specific strength and durability requirements.

Improved Surface Finish: SCC provides a smooth and high-quality surface finish without the need for additional surface treatments or finishing techniques. This is beneficial in architectural applications where an aesthetically pleasing appearance is desired.

Enhanced Workability Retention: SCC has good workability retention, meaning it remains highly workable for an extended period, allowing for longer transportation and pouring times. This is particularly advantageous in large-scale or complex construction projects.

The production of SCC involves careful selection of materials, mix design optimization, and often the use of chemical admixtures. The mix design must consider factors such as the desired flowability, aggregate grading, cementitious content, water-to-powder ratio, and the incorporation of suitable mineral admixtures or supplementary cementitious materials.

SCC offers several benefits in construction, including improved construction speed, enhanced productivity, reduced labor requirements, and better overall quality control. It is commonly used in applications such as precast concrete elements, heavily reinforced structures, high-rise buildings, tunnel linings, and architectural concrete.

INDUSTRAIL WASTE MATERIALS

Figure 3: Industrial waste materials

Industrial waste materials refer to by-products or residues generated during industrial processes. These materials are typically considered as waste and require proper disposal or management. However, they can often be reused or recycled in various applications, including construction. Some common examples of industrial waste materials used in construction include:

- **Fly Ash:** Fly ash is a fine, powdery residue obtained from coal-fired power plants. It is rich in silica, alumina, and other reactive components, making it a valuable supplementary cementitious material in concrete production. Fly ash improves workability, reduces heat of hydration, and enhances the durability of concrete.
- **Slag:** Slag is a by-product of the iron and steel manufacturing industry. It is produced during the smelting process and consists of non-metallic compounds such as silicates and aluminosilicates. Ground granulated blast furnace slag (GGBFS) is a commonly used slag

in concrete production, providing enhanced strength, durability, and reduced heat ofhydration.

- **Silica Fume:** Microsilica, or silica fume, is a byproduct of the manufacturing of silicon metal and ferrosilicon alloy. Amorphous silicon dioxide is the main ingredient in this powder. Silica fume is highly reactive and pozzolanic in nature, contributing to improved concrete strength, density, and durability.
- **Rice Husk Ash:** Rice husk ash is obtained from the combustion of rice husks, a by-product of rice milling. It contains a high amount of amorphous silica, which acts as a pozzolanic material. Adding rice husk ash to concrete is a great way to make it more resistant to the damaging effects of sulfate and chloride.
- **Bottom Ash:** Bottom ash is the coarse, granular byproduct of burning coal in thermal power plants. It may be used as a coarser substitute for aggregates in concrete than fly ash. Bottom ash helps to increase the workability of concrete and lower the heat of hydration.
- **Waste Glass:** Waste glass from various industrial processes, such as glass manufacturing or recycling, can be crushed and used as a partial replacement for fine or coarse aggregates in concrete. Glass particles can enhance the workability, aesthetic appearance, and reduce the alkali-silica reaction potential in concrete.
- **Industrial By-products:** Several other industrial by-products, such as foundry sand, quarry dust, wood ash, and various mining and manufacturing residues, can be utilized as supplementary materials in concrete production. Their specific properties and potential benefits depend on the type of industry and the composition of the by-product.

The use of industrial waste materials in construction offers several advantages, including reduced environmental impact, conservation of natural resources, and improved sustainability. However, their suitability and performance in concrete applications must be evaluated through testing and research to ensure compliance with industry standards and specifications.

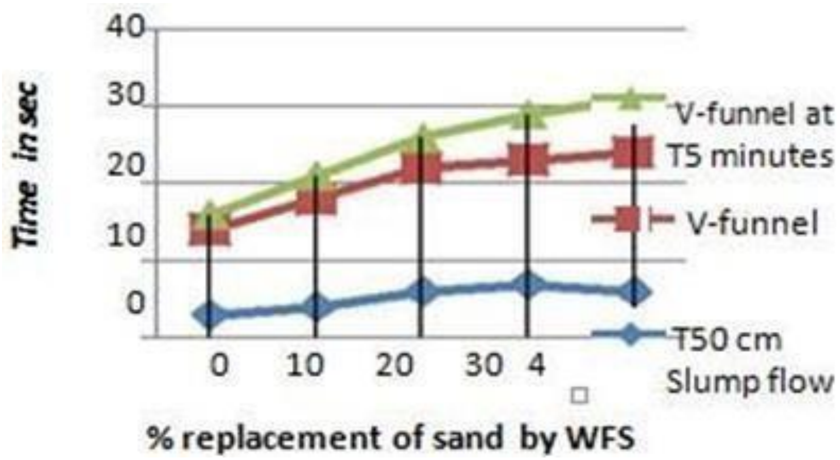
III. RESULTS & DISCUSSION

Compressive strength, Flexural strength, and Split tensile strength of SCC with varied percentages of waste foundry sand were determined by experimental investigation. Compressive strength after 7 days is measured using a compression testing equipment. Below are the specifics of both the fresh concrete test and the hardened concrete test: Probing on new concrete: The design is heavily influenced by the self compacting concrete's workability. Therefore, tests like the Slump flow, V Funnel, L Box, and J Ring test are used to establish whether or not the SCC is workable with waste foundry sand. Table VII displays the outcome of SCC using discarded foundry sand.

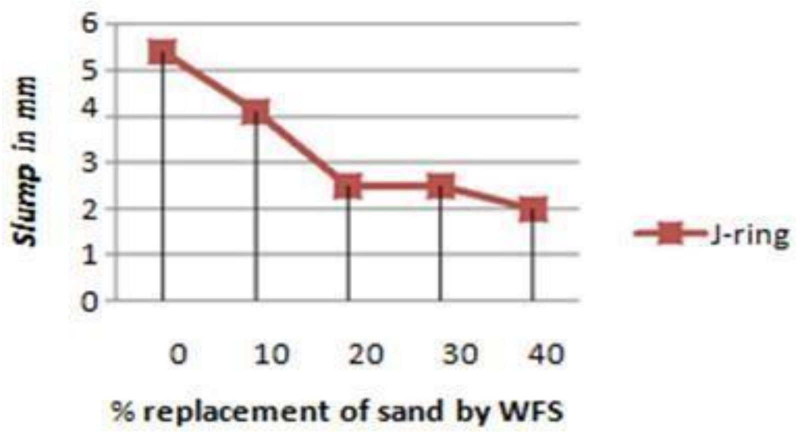
Table No. 7 Results for Workability of Scc With WFS

Sr. No.	Workability of SCC by	Percentage Replacement Of WFS In NS				
		0%	10%	20%	30%	40%
1	Slump flow mm	695	680	672	655	640
2	T_{50cm} Slump flow sec	3	3	5	6	6
3	J-ring mm	5	6.5	8	10.5	12
4	V-funnel sec	11	12	15	15	17
5	V-funnel at T_5 minutes sec	15	14	17	18	20
6	L-box H_2/H_1	0.9	0.75	0.6	0.55	0.55

Graph 1: Results for Workability of SCC with WFS by various tests



Graph 2: Results for Workability of SCC with WFS by J-ring



Compressive strength tests were performed on concrete cube specimens for 7 and 28 days on hard concrete. Beam specimens aged for 28 days will be used to calculate the flexure strength of SCC using WFS, while concrete cylinders will be used to calculate the split tensile strength of the material. For SSC control specimens and for different percentages of waste foundry sand, 7-day strength of the concrete cube specimens have been performed so far. The weight of SCC with WFS is also taken into account by studying the density of SCC with WFS. The compressive strength of SCC control specimens and SCC with WFS after 7 days is shown in Tables 8 and 9 below.

Table No. 8 Results for 7 Days Compressive Strength of Scc With WFS

Sr.No.	Designation	Compressive strength at 7 days	Avg. Compressive Strength at 7 days
1	SCC-0%1	29.14 N/ mm2	27.83 N/ mm2
	SCC-0%2	28.69 N/ mm2	
	SCC-0%3	25.67 N/ mm2	
2	SCC-10%1	22.33 N/ mm2	21.68 N/ mm2
	SCC-10%2	19.25 N/ mm2	
	SCC-10%3	23.47 N/ mm2	
3	SCC-20%1	16.52 N/ mm2	15.77 N/ mm2
	SCC-20%2	15.87 N/ mm2	
	SCC-20%3	14.93 N/ mm2	
4	SCC-30%1	15.96 N/ mm2	14.56 N/ mm2
	SCC-30%2	12.58 N/ mm2	
	SCC-30%3	15.16 N/ mm2	
5	SCC-40%1	14.22 N/ mm2	13.05 N/ mm2
	SCC-40%2	12.67 N/ mm2	
	SCC-40%3	12.27 N/ mm2	

Graph 3: Results for 7 days Compressive strength of SCC with WFS

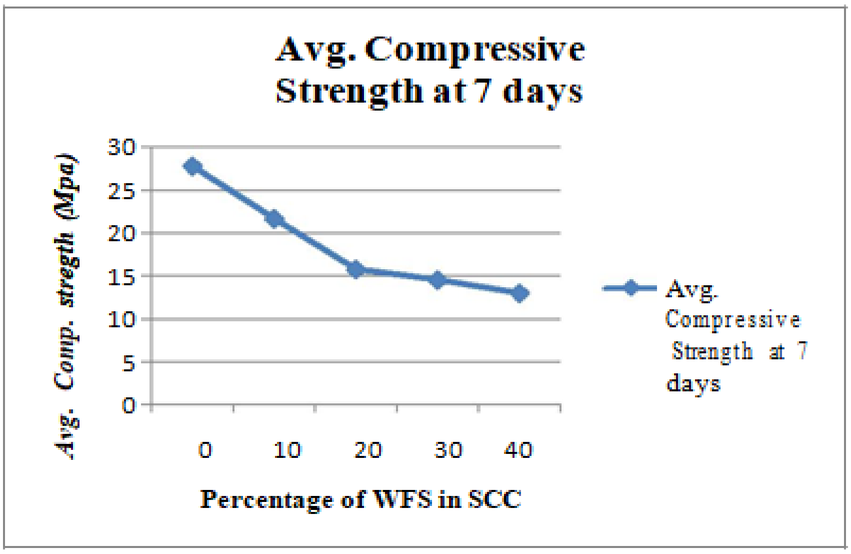


Table 8: Results for 14 Days Compressive Strength of Scc With WFS

Sr. No.	Designation	Compressive strength at 14 days	Avg. Compressive Strength at 14days
1	SCC-0%1	31.15 N/ mm2	29.83 N/ mm2
	SCC-0%2	29.68 N/ mm2	
	SCC-0%3	26.65 N/ mm2	
2	SCC-10%1	25.22 N/ mm2	23.68 N/ mm2
	SCC-10%2	21.15 N/ mm2	
	SCC-10%3	24.56 N/ mm2	
3	SCC-20%1	17.63 N/ mm2	19.77 N/ mm2
	SCC-20%2	18.98 N/ mm2	
	SCC-20%3	15.85 N/ mm2	
4	SCC-30%1	16.87 N/ mm2	18.56 N/ mm2
	SCC-30%2	13.69 N/ mm2	
	SCC-30%3	16.27 N/ mm2	
5	SCC-40%1	15.33 N/ mm2	17.05 N/ mm2
	SCC-40%2	13.78 N/ mm2	
	SCC-40%5	13.38 N/ mm2	

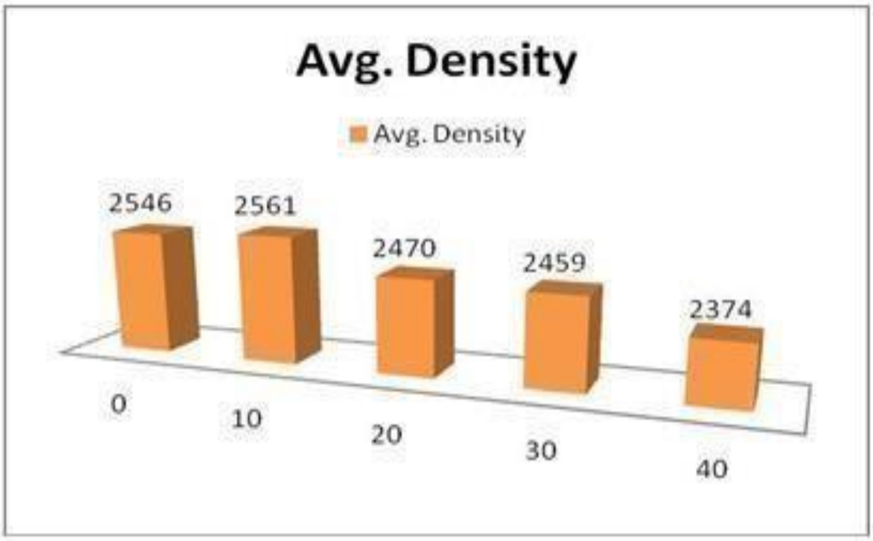
Table 8: Results for 24 Days Compressive Strength of Scc With WFS

Sr.No.	Designation	Compressive strength at 14 days	Avg. Compressive Strength at 14 days
1	SCC-0%1	31.15 N/ mm2	29.83 N/ mm2
	SCC-0%2	29.68 N/ mm2	
	SCC-0%3	26.65 N/ mm2	
2	SCC-10%1	25.22 N/ mm2	23.68 N/ mm2
	SCC-10%2	21.15 N/ mm2	
	SCC-10%3	24.56 N/ mm2	
3	SCC-20%1	17.63 N/ mm2	19.77 N/ mm2
	SCC-20%2	18.98 N/ mm2	
	SCC-20%3	15.85 N/ mm2	
4	SCC-30%1	16.87 N/ mm2	18.56 N/ mm2
	SCC-30%2	13.69 N/ mm2	
	SCC-30%3	16.27 N/ mm2	
5	SCC-40%1	15.33 N/ mm2	17.05 N/ mm2
	SCC-40%2	13.78 N/ mm2	
	SCC-40%3	13.38 N/ mm2	

Table No 9 Results for Density in Kg/M3 of Scc With WFS

Sr.No.	Designation	Density in kg/m3	Avg. Density in kg/m3
1	SCC-0%1	2467	2546
	SCC-0%2	2590	
	SCC-0%3	2581	
2	SCC-10%1	2432	2561
	SCC-10%2	2615	
	SCC-10%3	2636	
3	SCC-20%1	2447	2459
	SCC-20%2	2434	
	SCC-20%3	2495	
4	SCC-30%1	2371	2470
	SCC-30%2	2381	
	SCC-30%3	2657	
5	SCC-40%1	2376	2374
	SCC-40%2	2376	
	SCC-40%5	2370	

Graph 4: Results for Density in Kg/m3 of SCC with WFS



IV. CONCLUSION

Workability observed for the control specimen is well within the allowable range established by the European Code, as shown by the results obtained for different tests of workability of SCC control specimen and SCC with WFS. So, it gives the green light to SCC's mix design. From Graph 1, it is possible to infer that the workability obtained by the Abram cone test diminishes with increasing percentages of waste foundry sand, with the greatest reduction in workability seen for 20% substitution of WFS in SCC. Similar workability behavior was also seen with other approaches. It follows that the SCC is less practical when using WFS. Compression testing equipment was used to evaluate the typical compressive strength of concrete after 7 days. The average compressive strength was calculated as indicated in the preceding graph. Density trends are shown in Graph 4 for both untreated SCC and SCC treated with WFS. The results show that when the fraction of WFS in SCCs grows, their density falls. The reason for this is because WFS is lighter than natural sand.

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