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Cost-Effective Self-Compacting Concrete by using Fly Ash

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Abstract. Self-compacting concrete (SCC) has gained significant attention in recent years due to its exceptional flow ability and ease of placement, which eliminate the need for mechanical consolidation. In this study, the effect of incorporating fly ash as a partial replacement of cement in SCC is investigated. Three different replacement levels, namely 10%, 15%, and 20%, were examined to assess their impact on the fresh and hardened properties of SCC. The objective of this research is to evaluate the feasibility of utilizing fly ash in SCC and determine the optimum replacement level that provides enhanced performance while maintaining the required structural integrity. This study focuses on the rheological properties, compressive strength, and durability characteristics of SCC incorporating fly ash. The rheological properties were assessed through slump flow, T50 time, and V-funnel flow tests to evaluate the work ability and flow ability of the mixtures. The compressive strength was determined at different ages to assess the mechanical performance of the hardened concrete. The durability properties investigated include water absorption, chloride ion penetration, and carbonation resistance. To accomplish the study objectives, a comprehensive experimental program was conducted, involving the preparation of SCC mixtures with varying fly ash replacement levels. The experimental results were compared with a control mixture containing no fly ash. The data obtained from the experiments were analyzed and evaluated to draw meaningful conclusions. The findings of this study reveal that the incorporation of fly ash in SCC has a notable influence on its fresh and hardened properties. The results indicate that the addition of fly ash up to 15% replacement level enhances the workability of SCC without significantly compromising its strength development. Beyond 15% replacement, a slight decrease in compressive strength is observed, although it remains within acceptable limits. Moreover, the durability properties of SCC improved with increasing fly ash content due to the pozzolanic reaction and refined microstructure .in-corporation fly ash as a partial replacement of cement in SCC demonstrates considerable potential to enhance the fresh and hardened properties of the concrete. The optimum fly ash replacement level of 15% is recommended to achieve an optimal balance between workability, strength development, and durability. This study contributes to the growing body of knowledge on sustainable concrete technology by exploring the utilization of fly ash in SCC, paving the way for more environmentally friendly construction practices.

Keywords: Cost-Effective; Self-Compacting; Fly Ash; Mechanical Properties.

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1. Introduction & Literature Review

Effect of Fly Ash on Fresh Properties of SCCA. (Kumar et al., 2015): The use of fly ash in SCC has a significant impact on its new properties, including performance and separation. Many studies have shown that the addition of fly ash improves the performance of SCC due to its ability to reduce water requirements and increase fines content. Use products and reduce fine flour.

Effect of Fly Ash on Mechanical Properties of SCC

- The mechanical properties of SCC are affected by the cementitious materials and type used. Partial r eplacement of cement with fly ash can improve th e compressive strength, tensile strength and flexur al strength of SCC (H. Safiuddin et al., 2013). Many studies have shown that the use of fl y ash improves mechanical properties in SCC. Usi ng fly ash instead of cement increases the compre ssive strength of SCC1.2.3 Effect of Fly Ash on Durability of SCC.
- The durability of SCC is an important aspect that needs to be considered in its production (M. (Soroushian et al., 2014). The incorporation of fly ash in SCC can enhance its durability by reducing permeability, increasing resistance to chemical attack, and reducing the risk of cracking. Several studies have shown that the use of fly ash in SCC can improve its durability. The use of fly ash as a partial replacement of cement improved the resistance of SCC to chloride ion penetration.

Investigated the use of fly ash in SCC with different percentages of replacement

- The use of fly ash in SCC at different conversion rates (10%, 20%, 30% and 40%) was investigated (Siddique and Khan 2011). .Research studies have shown that SCC made wit h 20% fly ash replacement has good compressive strength, good workability and durability, and als o reduces the overall cost of concrete

Research Objectives

1 To assess the effect of incorporating fly ash at different replacement levels (10%, 15%, and 20%) on the fresh properties of self-compacting concrete (SCC).

2 Evaluate the workability of SCC through slump flow, T50 time, and V-funnel flow tests.

3 Investigate the influence of fly ash on the viscosity, stability, and segregation resistance of SCC.

4 To investigate the impact of fly ash replacement on the hardened properties of SCC.

5 Determine the compressive strength of SCC at different ages (e.g., 7 days, 28 days) to assess the strength development.

6 Evaluate the flexural strength and tensile strength of SCC to understand the effect of fly ash on the structural performance.

7 To analyze the durability properties of SCC incorporating fly ash.

8 Assess the resistance to chloride ion penetration using rapid chloride permeability tests.

9 Evaluate the water absorption and permeability of SCC to determine its resistance to moisture ingress.

10 Investigate the carbonation resistance of SCC to understand its durability in carbonated environments.

11 To optimize the mix proportions of SCC with different fly ash replacement levels.

12 Determine the appropriate water-cement ratio and super plasticizer dosage to achieve the desired workability and strength.

13 Investigate the influence of fly ash content on the optimal mix design to balance performance and sustainability.

14 To compare the performance of SCC with different fly ash replacement levels to a control mixture without fly ash.

15 Evaluate and compare the fresh, hardened, and durability properties of SCC with varying fly ash replacement levels.

16 Analyze the results to determine the optimum replacement level of fly ash that provides enhanced performance while maintaining the required structural integrity.

2. Research Methodology

Mechanical Properties of Mix 1

Compressive Strength of Mix 1

The mix 1 is convectional concrete which is normally used M20 concrete. We cast cubes for checking compressive strength test. Three cubes are casted for mix 1.After casting concrete cubes are cured in water tank for 28 days. And after we checked their compressive strength on compression machine. Average compressive strength of cubes after 28 days is 32.3 MPa.

Tensile Strength Of Mix 1: The tensile strength of concrete after 28 days can vary depending on several factors, including the mix design, curing conditions, and quality of materials used. However, a tensile strength 4.05 N/mm2 (or MPa) for M20 concrete after 28 days is relatively low.M20 concrete typically has a characteristic compressive strength of 32.30 N/mm2 after 28 days. The tensile strength of concrete is generally lower than its compressive strength, typically ranging from about 10% to 15% of the compressive strength. Therefore, for M20 concrete, the expected tensile strength after 28 days would be around 3 N/mm2 to 4 N/mm^2.

Flexural Strength of Mix 1

The flexural strength of concrete is typically expressed in terms of the modulus of rupture, which represents the maximum bending moment that concrete can withstand before failure in flexure. In your case, if the flexural strength of concrete after 28 days for an M20 mix design is reported as 4.07 N/mm², it means that the concrete has a modulus of rupture or flexural strength of 4.07 N/mm².

Mechanical Properties of Mix 2

Compressive Strength of Mix 2

The mix 2 is self-compacting concrete by 15% fly ash. We cast cubes for checking compressive strength test. Three cubes are casted. After casting concrete cubes are cured in water tank for 28 days. And after we checked their compressive strength on compression machine. Average compressive strength of cubes after 28 days is 34.12 N/mm2. The compressive strength of 34.12 N/mm² after 28 days for M20 grade in self-compacting concrete by adding 15% fly ash concrete with indicates the load- carrying capacity and quality of the concrete. The compressive strength is determined by conducting standard tests on concrete samples, typically cubes, and subjecting them to a compressive force until failure occurs. In the case the compressive strength requirement after 28 days is typically specified as a minimum value. The value of 32.12 N/mm² suggests that the concrete has achieved a satisfactory level of strength development. Compressive strength of Mix 2 is greater from Mix 1.

Tensile Strength of Mix 2

Tensile Strength Test performed on cylinders. The mix 2 self-compacting concrete by 15% fly ash. The tensile strength of concrete after 28 days can vary depending on several factors, including the mix design, curing conditions, and quality of materials used. However, a tensile strength of 4.01 N/mm2 (or MPa) for SCC concrete after 28 days is relatively low. SCC concrete typically has a characteristic compressive strength of 34.12 N/mm2 after 28 days. The tensile strength of concrete is generally lower than its compressive strength, typically ranging from about 10% to 15% of the compressive strength. Therefore, for SCC, the expected tensile strength after 28 days would be around 3.56 N/mm^2 to 2.6 N/mm^2.This show that tensile strength of mix 2 is lower than from mix 1.

Flexural Strength of Mix 2

Flexural strength check on beams. A flexural strength value of 4.06 N/mm^2 for concrete using SCC by adding 15% fly ash suggests the material's ability to resist bending forces. However, it is important to note that the flexural strength of concrete depends on various factors, including the m$_3$ix$_5$ design, water-cement ratio, aggregate properties, curing conditions, and the quality of fly ash**.** In this case, if the flexural strength of concrete after 28 days s for an SCC is reported as 4.06 N/mm^2, it means that the concrete has a modulus of rupture or flexural strength of 4.06 N/mm^2.The Flexural strength of mix 2 is lower than from mix 1.

Mechanical Properties of Mix 3

Compressive Strength of Mix 3

The mix is self-compacting concrete by 20% fly ash. We cast cubes for checking compressive strength test .Three cubes are casted. After casting concrete cubes are cured in water tank for 28 days. And after we checked their compressive strength on compression machine. Average compressive strength of cubes after 28 days is 36.15 N/mm2. The compressive strength of 36.15 N/mm^2 after 28 days for M20 grade in self-compacting concrete by adding 20% fly ash concrete with indicates the load- carrying capacity and quality of the concrete. The compressive strength is determined by conducting standard tests on concrete samples, typically cubes, and subjecting them to a compressive force until failure occurs. In the case the compressive strength requirement after 28 days is typically specified as a minimum value. The value of 36.15 N/mm^2 suggests that the concrete has achieved a satisfactory level of strength development. Compressive strength of Mix 3 is lower from Mix 1.

Tensile Strength of Mix 3

Tensile Strength Test performed on cylinders. The mix 2 self-compacting concrete by 20% fly ash. The tensile strength of concrete after 28 days can vary depending on several factors, including the mix design, curing conditions, and quality of materials used. However, a tensile strength of 4.04 N/mm2 (or MPa) for SCC concrete after 28 days is relatively low. SCC concrete typically has a characteristic compressive strength of 36.15 N/mm2 after 28 days. The tensile strength of concrete is generally lower than its compressive strength, typically ranging from about 10% to 15% of the compressive strength.

Flexural Strength of Mix 3

Flexural strength check on beams. A flexural strength value of 4.09 N/mm^2 for concrete using SCC by adding 20% fly ash suggests the material's ability to resist bending forces. However, it is important to note that the flexural strength of concrete depends on various factors, including the mix design, water-cement ratio, aggregate properties, curing conditions, and the quality of fly ash**.** In this case, if the flexural strength of concrete after 28 days for an SCC is reported as 4.09 N/mm^2, it means that the concrete has a modulus of rupture or flexural strength of 4.09 N/mm^2.

Mechanical Properties of Mix 3

Compressive Strength of Mix 4

The mix is self-compacting concrete by 25% fly ash. We cast cubes for checking compressive strength test. Three cubes are casted. After casting concrete cubes are cured in water tank for 28 days. And after we checked their compressive strength on compression machine. Average compressive strength of cubes after

28 days is 28.28 N/mm^2. The compressive strength of 28.28 N/mm² after 28 days for M20 grade in self-compacting concrete by adding 20% fly ash concrete with indicates the load- carrying capacity and quality of the concrete. The compressive strength is determined by conducting standard tests on concrete samples, typically cubes, and subjecting them to a compressive force until failure occurs .In the case the compressive strength requirement after 28 days is typically specified as a minimum value. The value of 28.28/mm² suggests that the concrete has achieved a satisfactory level of strength development .Compressive strength of Mix 4 is lower from Mix 1.

Tensile Strength of Mix 3

Tensile Strength Test performed on cylinders. The mix 4 self-compacting concrete by 25% fly ash. The tensile strength of concrete after 28 days can vary depending on several factors, including the mix design, curing conditions, and quality of materials used. However, a tensile strength of 3.86 N/mm2 (or MPa) for SCC concrete after 28 days is relatively low. The tensile strength of concrete is generally lower than its compressive strength, typically ranging from about 10% to 15% of the compressive strength. Therefore, for SCC, the expected tensile strength after 28 days would be around 3.86 N/mm^2.

Flexural Strength of Mix 4

Flexural strength check on beams. A flexural strength value of 3.89 N/mm² for concrete using SCC by adding 25% fly ash suggests the material's ability to resist bending forces. However, it is important to note that the flexural strength of concrete depends on various factors, including the mix design, water-cement ratio, aggregate properties, curing conditions, and the quality of fly ash**.** In this case, if the flexural strength of concrete after 28 days for an SCC is reported as 3.89 N/mm², it means that the concrete has a modulus of rupture or flexural strength of 3.89 N/mm². The Flexural strength of mix 4 is lower than from mix 1.

Mitigated Heat of Hydration

A higher percentage of fly ash can help reduce the heat generated during cement hydration, which in turn minimizes the risk of thermal cracking and enhances the concrete's long-term durability.

Durability of Concrete

Durability Implication

While SCC without fly ash can still exhibit good properties, the addition of fly ash can enhance its durability even further.

Fly Ash 15%

Improved Workability: Fly ash can improve the workability of SCC, leading to easier placement and compaction without the need for excessive vibration.

Reduced Permeability: The incorporation of 15% fly ash can densify the microstructure of the concrete, resulting in lower permeability. This reduces the ingress of water and harmful ions, enhancing the concrete's resistance to chemical attack, sulfate attack, and chloride penetration.

Enhanced Long-Term Strength: Fly ash contributes to long-term strength development, potentially leading to improved overall structural integrity.

Fly Ash 20 %Sustainable Concrete: The use of 20% fly ash reduces the demand for traditional cement, leading to a smaller carbon footprint and promoting sustainability.

Fly Ash 25%

Higher Pozzolanic Activity: With 25% fly ash content, the concrete's pozzolanic activity is more pronounced. This contributes to the formation of additional cementitious compounds over time, enhancing strength and durability.

Lower Permeability: The high fly ash content results in a more refined microstructure, further lowering the permeability of the concrete.

Extended Service Life: The improved microstructure, along with enhanced strength and durability, can extend the service life of structures made with SCC.

Water Absorption of self-compacting concrete Mix 1: The water absorption of Self-Compacting Concrete (SCC) is an important property that relates to its durability and resistance to various forms of deterioration, including freeze-thaw cycles and chemical attack. Water absorption is typically measured as the amount of water absorbed by the concrete over a certain period of time. It's influenced by factors such as mix design, aggregate properties, curing conditions, and the presence of additives like fly ash.

Water Absorption of Mix 2: Adding 15% fly ash to SCC can result in a water absorption reduction of around 10% to 20% compared to SCC without fly ash. This means that if the water absorption of SCC without fly ash is, for example, around 4%, you might expect the water absorption of SCC with 15% fly ash to be in the range of approximately 3% to 3.6%. These values are approximate and can vary.

Water Absorption of Mix 3

Incorporating 20% fly ash into SCC could potentially lead to a reduction in water absorption of 15% compared to SCC without fly ash.

Water Absorption of Mix 4

Incorporating 25% fly ash into SCC could potentially lead to a water absorption reduction of around 10% to 20% compared to SCC without fly ash.

3. Results and Discussions

Testing Results

Table 1 Simple Self-Compacting concrete PCC (1:2:4) w/c 0.9

Name of Specimens	Test Name	7 Days Test in MPa	14 Days Test in MPa	28 Days Test in MPa
Cube	Compression	24.02	30.3	32.3
Cylinder	Tensile	3.02	3.65	4.05
Beam	Flexural	3.13	3.78	4.07

Table 2 Self-Compacting Concrete by using 15% Fly ash (1:2:4) w/c 0.9

Name of Specimens	Test Name	7 Days Test in MPa	14 Days Test in MPa	28 Days Test in MPa
Cube	Compression	18.79	28.15	34.12
Cylinder	Tensile	2.98	3.52	4.01
Beam	Flexural	3.09	3.69	4.06

Table 3 Self-Compacting Concrete by using 20% Fly ash (1:2:4) w/c 0.9

Name of Specimens	Test Name	7 Days Test in MPa	14 Days Test in MPa	28 Days Test in MPa
Cube	Compression	20.19	29.18	36.15
Cylinder	Tensile	3.06	3.88	4.04
Beam	Flexural	3.15	3.75	4.09

Table 4 Self-Compacting Concrete by using 25% Fly ash (1:2:4) w/c 0.9

Name of Specimens	Test Name	7 Days Test in MPa	14 Days Test in MPa	28 Days Test in MPa
Cube	Compression	12.82	25.61	28.28
Cylinder	Tensile	2.99	3.39	3.86
Beam	Flexural	2.89	3.25	3.89

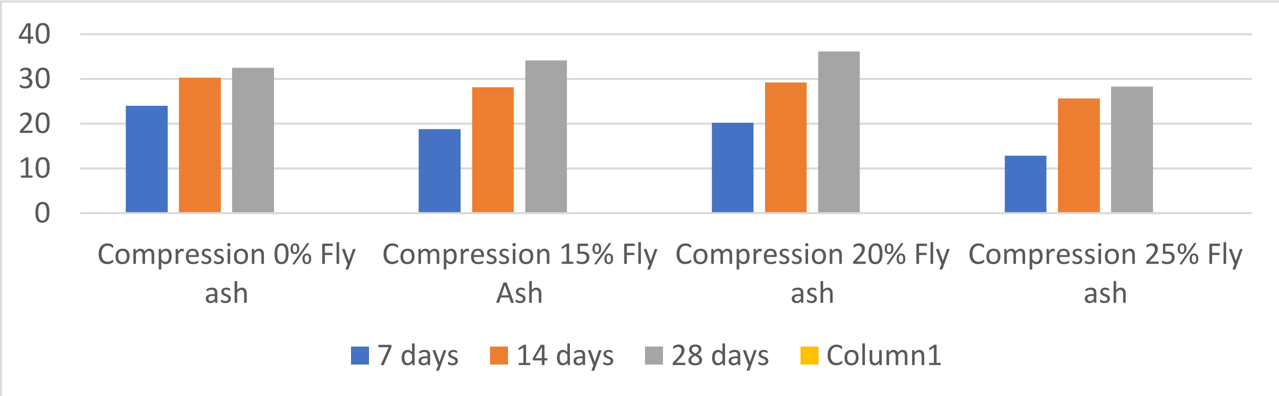

Figure 1 Compression Test Results of all Mixes on 7, 14 & 28 Days

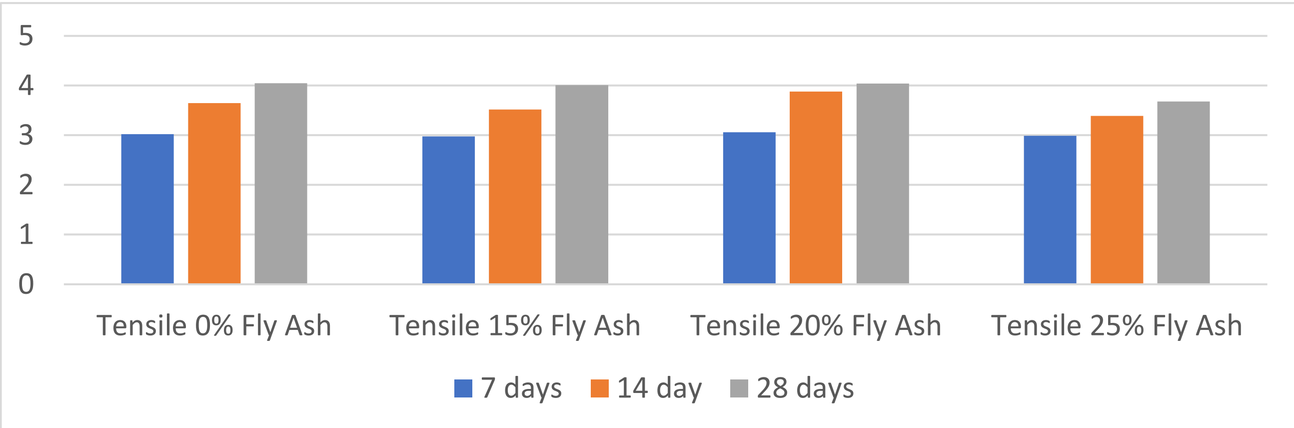

Figure 2 Tensile Test Results of all Mixes on 7, 14 & 28 Days

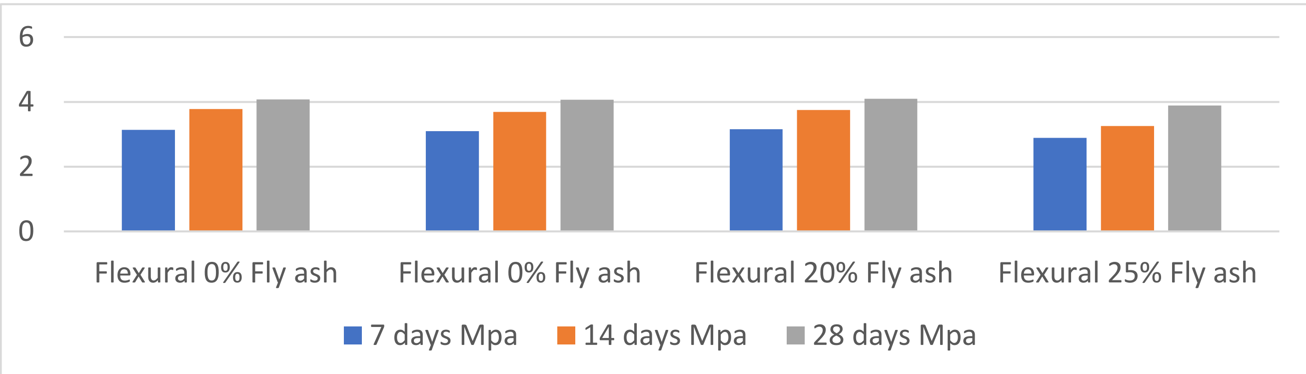

Figure 3 Flexure Test Results of all Mixes on 7, 14 & 28 Days

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