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Effect of Silt Contamination in Fine Aggregates on the Strength Properties of Self-Compacting Concrete

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Abstract: *Self-Compacting Concrete (SCC) has gained widespread acceptance in modern construction due to its superior flowability, self-consolidation ability, and enhanced structural quality. However, SCC performance is highly sensitive to variations in fine aggregate quality, particularly silt contamination. In many regions, fine aggregates used in construction contain excessive silt due to insufficient washing and quality control. This study experimentally investigates the effect of silt contamination in fine aggregates on the fresh and hardened properties of SCC. Fine aggregates with controlled silt contents of 0%, 2%, 4%, 6%, and 8% were used to prepare M30 grade SCC mixes. Fresh properties were evaluated using slump flow, V-funnel, L-box, and J-ring tests, while hardened properties were assessed through compressive, split tensile, and flexural strength tests. The results indicate that silt content up to 3–4% does not significantly impair SCC performance; however, higher silt contents lead to substantial reductions in workability, strength, and durability. The study recommends a maximum permissible silt content of 3–4% for structural SCC applications.*

Keywords: *Self-Compacting Concrete, Silt Content, Fine Aggregates, Workability, Compressive Strength, Durability*

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I. Introduction:

Concrete is the most extensively used construction material worldwide due to its versatility, durability, and relatively low cost. With the growing demand for complex structural forms, increased reinforcement congestion, and higher construction efficiency, conventional vibrated concrete often encounters challenges such as inadequate compaction, segregation, poor surface finish, and heavy dependence on skilled labour. To overcome these limitations, Self-Compacting Concrete (SCC) was developed in Japan in the late 1980s by Okamura and Ouchi [1]. SCC is designed to flow under its own weight, completely fill formwork, and encapsulate reinforcement without the need for external vibration, thereby ensuring uniform quality, improved durability, and enhanced construction efficiency. Day by day the urbanization increases due to population migration toward cities, so the clean water demand increased, and hence, the water security becoming more important [7].

The successful performance of SCC depends on achieving a delicate balance between flowability, passing ability, and segregation resistance, which together define its self-compacting nature. This balance is governed primarily by the quality and proportioning of constituent materials, including cement, water, fine and coarse aggregates, mineral fillers, and chemical admixtures [1]. Among these components, fine aggregates play a particularly critical role, as they directly influence the rheological behaviour, stability, and mechanical properties of SCC. The particle size distribution, surface texture, shape, and cleanliness of fine aggregates significantly affect viscosity control, resistance to segregation, and strength development in SCC mixes [5].

One of the most common quality issues associated with fine aggregates is silt contamination. Silt consists of very fine particles, typically smaller than 75 µm, that pass through standard sieves and adhere to the surface of sand grains. These particles originate from natural deposits, inadequate washing of river sand, improper storage practices, or the use of unprocessed manufactured sand [2]. While a limited number of fines may enhance cohesiveness and particle packing, excessive silt content adversely affects both fresh and hardened properties of concrete. Silt particles increase water demand, interfere with cement hydration, and weaken the bond between cement paste and aggregates, particularly within the interfacial transition zone (ITZ) [2,3].

Standards such as IS 383 and ASTM C33 limit the permissible silt content in fine aggregates to approximately 3–5% by weight. However, in practical construction scenarios—especially in developing regions—fine aggregates with silt contents exceeding these limits are frequently used due to the scarcity of clean sand and economic constraints [3,4]. This practice often results in inconsistent concrete quality, reduced mechanical strength, and compromised durability. The problem becomes more critical in SCC, as it is more sensitive to variations in fine material content than conventional concrete. Even small deviations in silt content can significantly alter SCC rheology, leading to loss of self-compacting ability or increased risk of segregation [1,5].

Although numerous studies have investigated the effect of silt contamination in conventional concrete, systematic investigations focusing on SCC with controlled silt contamination levels remain limited. Given the increasing use of SCC in high-rise buildings, precast structures, and infrastructure projects, it is essential to clearly define the permissible silt limits that can be tolerated without compromising performance. Therefore, the present study aims to experimentally evaluate the effect of varying silt contents in fine aggregates on the fresh and hardened properties of SCC and to establish an optimal silt limit suitable for structural applications.

II. Literature Review:

2. Literature Review:

The quality of fine aggregates has long been recognized as a key factor influencing the performance of concrete. Numerous studies have demonstrated that impurities such as silt, clay, and dust particles significantly affect workability, strength, and durability characteristics of both conventional and self-compacting concrete.

2.1 Effect of Silt on Conventional Concrete:

Early research on conventional concrete established that excessive silt content increases water demand and leads to a reduction in compressive strength. Cho [2] reported that high silt fines disrupt the cement–aggregate bond, resulting in increased porosity, permeability, and reduced durability performance. The presence of silt particles was shown to weaken the interfacial transition zone, which plays a critical role in stress transfer within concrete.

Shaikh and Shete [3] experimentally investigated concrete mixes with varying silt contents and observed a progressive reduction in compressive strength when silt content exceeded approximately 6%. Their study highlighted that silt particles coat sand grains, preventing effective bonding with cement paste and reducing overall matrix integrity. Similar trends were observed in tensile strength and durability-related parameters.

Qumer and Kumar [4] studied the partial replacement of fine aggregate with Mersey silt in M20 grade concrete. Their results indicated that limited replacement levels could be tolerated without severe strength loss; however, higher silt contents caused significant reductions in compressive and split tensile strength. Khub Chand Sahu and Alok Krishnan (2021) further emphasized that the cleanliness of fine aggregates is critical for achieving consistent concrete performance and structural reliability.

2.2 Fine Aggregate Quality and Alternative Materials:

To address the scarcity of natural river sand, several researchers have explored alternative fine aggregates such as quarry dust, manufactured sand, and stone dust. Debabrata Paul and Neog (2020) reported that crusher stone dust could partially replace river sand; however, workability decreased due to increased fine content, necessitating the use of superplasticizers. George et al. (2008) demonstrated that manufactured sand with controlled fines improved particle packing and compressive strength when properly graded.

Although these alternative materials often contain higher fine fractions, studies consistently emphasize that controlled fines differ fundamentally from uncontrolled silt contamination. While engineered mineral fillers may enhance packing density and strength, random silt contamination adversely affects hydration processes and bonding mechanisms [2,3].

2.3 Silt Contamination in Self-Compacting Concrete:

Research focusing on SCC indicates that it is significantly more sensitive to fine aggregate impurities than conventional concrete. Okamura and Ouchi [1] emphasized that SCC requires strict quality control of fine materials to maintain self-compatibility, stability, and segregation resistance. Rajasekaran et al. [5] compared SCC with conventional concrete and reported superior strength and durability in SCC when aggregate quality was carefully controlled.

Cho [2] observed that silt fines increase plastic viscosity and reduce durability-related properties, including resistance to permeability and shrinkage. Al-Ameri (2020) reported that SCC mixes containing excessive silt required higher dosages of superplasticizers to maintain flowability, which negatively influenced strength development and long-term performance.

Despite these findings, most existing studies focus either on conventional concrete or on SCC incorporating alternative fine materials. There remains a lack of systematic experimental data quantifying the effect of controlled silt contamination levels on the strength properties of SCC, particularly under Indian construction conditions. This research addresses this gap by evaluating SCC mixes with controlled silt contents and assessing their impact on fresh and hardened properties.

III. Materials and Methodology:

3.1 Materials

- **Cement:** Ordinary Portland Cement (OPC 53 Grade) conforming to IS 12269
- **Fine Aggregate:** Natural river sand with controlled silt contents
- **Coarse Aggregate:** Crushed stone (10–20 mm)
- **Admixture:** Polycarboxylate-based superplasticizer
- **Water:** Potable water

3.2 Experimental Program:

Fine aggregates were initially washed to remove impurities and dried. Controlled silt contents of 2%, 4%, 6%, and 8% were added by volume. A reference mix with 0% silt was also prepared. All SCC mixes were designed for M30 grade following IS 10262 guidelines. [13,15]

3.3 Tests Conducted:

Fresh Concrete Tests

- Slump Flow Test
- V-Funnel Test
- L-Box Test
- J-Ring Test

Hardened Concrete Tests

- Compressive Strength (7, 14, and 28 days)
- Split Tensile Strength (28 days)
- Flexural Strength (28 days)

IV. Experimental Results:

4.1 Sieve Analysis and Aggregate Properties

Table 1. Sieve Analysis Results of Fine Aggregate

Sieve Size (mm)	% Passing
4.75	100
2.36	96
1.18	82
600 µm	58
300 µm	22
150 µm	6

4.2 Silt Content Test

Table 2. Silt Content Results

Sample	Silt Content (%)
Clean Sand	0
Mix S2	2
Mix S4	4
Mix S6	6
Mix S8	8

4.3 Fresh Properties of SCC

Table 3. Fresh Properties of SCC

Silt %	Slump Flow (mm)	V-Funnel (s)	L-Box Ratio
0	720	7.5	0.95
2	705	8.0	0.93
4	690	8.8	0.90
6	650	11.5	0.82
8	610	14.2	0.75

Flowability decreases significantly beyond 4% silt due to increased internal friction and water absorption.

4.4 Compressive Strength Results

Table 4. Compressive Strength Results

Silt %	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
0	28.4	36.8	42.5
2	27.6	35.9	41.3
4	26.2	34.1	39.2
6	23.5	30.6	35.8
8	21.4	27.9	31.6

4.5 Tensile and Flexural Strength

Table 5. Tensile and Flexural Strength (28 Days)

Silt %	Split Tensile (MPa)	Flexural (MPa)
0	3.9	5.4
2	3.7	5.2
4	3.5	5.0
6	3.1	4.5
8	2.7	4.0

V. Discussion

The results clearly indicate that silt contamination adversely affects both fresh and hardened properties of SCC. At low silt contents (≤4%), SCC maintains acceptable flowability and strength. However, beyond this threshold, excessive silt increases water demand, disrupts rheology, and weakens the interfacial transition zone (ITZ).

The reduction in compressive strength at higher silt contents (6–8%) reached 25%, consistent with findings by Cho [18] and Shaikh & Shete [7]. Increased porosity and microcracking contribute to reduced durability, making SCC vulnerable to long-term deterioration.

VI. Conclusions

1. Silt contamination significantly influences SCC performance.
2. SCC mixes with silt content up to 3–4% show acceptable workability and strength.
3. Silt contents beyond 6% cause severe reductions in compressive, tensile, and flexural strength.
4. Excess silt weakens the cement–aggregate bond and increases porosity.

5. For structural SCC applications, silt content should be limited to a maximum of 3–4%.

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