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BEHAVIOUR OF SELF-COMPACTING CONCRETE IN STRUCTURAL APPLICATIONS

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Abstract Self-Compacting Concrete (SCC) has emerged as a revolutionary construction material offering superior flowability, excellent passing ability, and high resistance to segregation without the need for mechanical vibration. These characteristics make SCC particularly advantageous in heavily reinforced structural elements, complex formwork, and high-performance construction environments. This review paper provides a consolidated assessment of the behaviour of SCC in structural applications, addressing its fresh and hardened properties, mix design considerations, rheology, durability, and mechanical performance. Recent research highlights the critical influence of admixtures, powder content, and aggregate gradation on achieving desirable SCC characteristics. Improvements in compressive strength, tensile resistance, modulus of elasticity, bond behaviour, and long-term durability make SCC suitable for beams, columns, slabs, prestressed members, and seismic-resistant structures. The paper also examines challenges related to shrinkage, creep, and sensitivity to material variation, which influence structural performance. Applications in high-rise buildings, bridges, precast construction, and repair works further validate its versatility. This review synthesizes literature published between 2005 and 2024 and identifies emerging trends such as fibre-reinforced SCC, self-healing SCC, and SCC incorporating industrial by-products aimed at sustainability. The study concludes that SCC enhances structural efficiency and construction quality, though optimization of mix design and field quality control remains critical for reliable performance.

Keywords:
Self-Compacting Concrete (SCC); Rheology; Structural Behaviour; Fresh Properties; Hardened Properties; High-Performance Concrete; Durability; Fibre-Reinforced SCC; Powder Content; Admixtures.

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1. Introduction

Self-Compacting Concrete (SCC) was first conceptualised in Japan during the late 1980s with the objective of ensuring high-quality concrete construction despite reduced availability of skilled labour for vibration (Okamura & Ouchi, 2003). SCC differentiates itself through its ability to compact under its own weight, characterised by high flowability, segregation resistance, and finishing ease. In modern structural engineering, SCC has become increasingly relevant due to the demand for faster construction, dense reinforcement, improved durability, and sustainable alternatives to conventional vibrated concrete (EFNARC, 2005). The introduction of viscosity-modifying admixtures and high-range water-reducing agents (HRWRAs) has further accelerated its adoption. Research in recent years highlights SCC's superior mechanical and durability performance compared to normal concrete, which enables its application in beams, columns, shear walls, precast members, and retrofitting projects (De Schutter et al., 2008).

2. Fresh Properties and Rheological Behaviour of SCC

Fresh behaviour is fundamental to SCC, determining its suitability for structural applications. SCC's fresh properties are governed by flowability, passing ability, and segregation resistance. Flowability allows the concrete to fill formwork under its own weight, measured through slump-flow and T50 tests (EFNARC, 2005). Passing ability enables SCC to navigate congested reinforcement without blocking, assessed using the L-box and J-ring tests. Segregation resistance is controlled through powder content and viscosity, often evaluated using the V-funnel test (Domone, 2007). Rheological parameters such as yield stress and plastic viscosity determine the workability window of SCC, which must remain stable during mixing, transportation, and placement to ensure uniformity in structural elements. Studies indicate that superplasticizers significantly reduce yield stress, while viscosity-modifying admixtures enhance cohesiveness (Bonen & Shah, 2005). Achieving an optimal balance between these components is essential to prevent defects such as settlement, bleeding, or honeycombing, which may compromise structural integrity.

3. Mix Design and Material Parameters of SCC

SCC requires a distinct mix design approach with a higher powder content, reduced coarse aggregate proportion, and the incorporation of HRWRAs and VMAs. Mix design guidelines proposed by Okamura and Ouchi (2003) and EFNARC (2005) emphasize that powder volume dictates flow characteristics and resistance to segregation. Supplementary cementitious

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materials (SCMs) such as fly ash, silica fume, ground granulated blast furnace slag (GGBFS), rice husk ash, and metakaolin improve cohesiveness and enhance mechanical performance (Sonebi, 2010). The reduced water–powder ratio improves compressive strength, while the optimized aggregate gradation minimizes inter-particle friction. Table 1 summarises common SCC mix design components. Variability in raw materials demands careful trial mixes and rheological adjustments. Sensitivity to moisture variation in aggregates and dosage inaccuracies of admixtures remain practical challenges influencing uniform performance in structural applications.

Table 1. Typical Mix Constituents of SCC and Their Functions

Constituent	Function in SCC
Cement & SCMs (fly ash, GGBFS, silica fume)	Improve powder content, strength, cohesiveness
Water	Adjusts workability; influences viscosity
Coarse Aggregate	Provides skeleton; must be limited to ensure flow
Fine Aggregate	Enhances filling ability and stability
HRWRAs	Reduce yield stress; increase flowability
VMAs	Improve segregation resistance and viscosity

4. Mechanical Properties of SCC

Mechanical performance governs SCC's suitability for structural applications. Compressive strength of SCC is generally comparable or superior to conventional concrete due to improved compaction and reduced voids (Kamal et al., 2014). Splitting tensile strength and flexural strength may vary depending on paste volume and aggregate distribution but generally show acceptable structural performance (Khaleel & Al-Mishhadani, 2012). SCC often exhibits a slightly lower modulus of elasticity due to its higher paste content, which may influence deflection predictions in beams (European Commission, 2007). Bond strength between SCC and reinforcing bars is typically higher owing to improved compaction around steel, which enhances anchorage and load transfer (Bui et al., 2002). Creep and shrinkage characteristics may be somewhat elevated compared to normal concrete, requiring modifications in long-term structural design, especially for prestressed members (De Schutter et al., 2008). Table 2 compares mechanical properties of SCC and conventional concrete.

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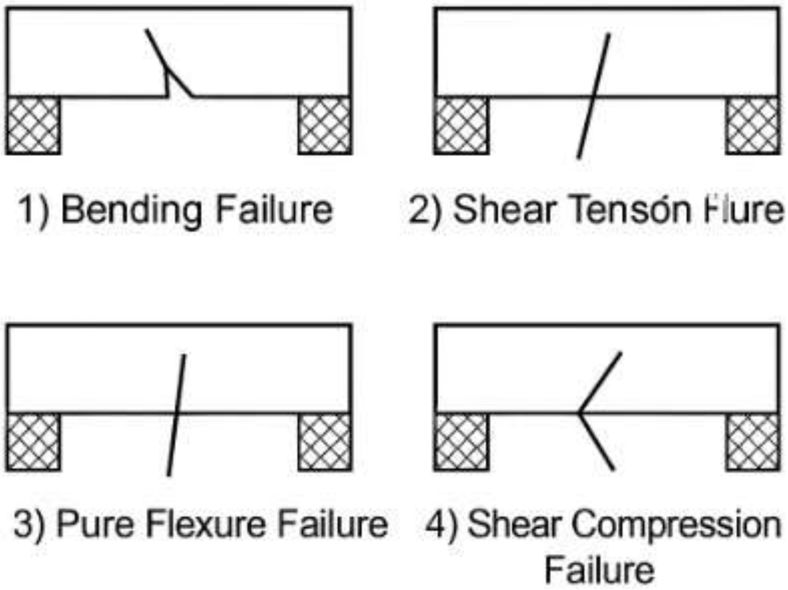

Figure 4.1 Failure Patterns in SCC Beams Under Flexure

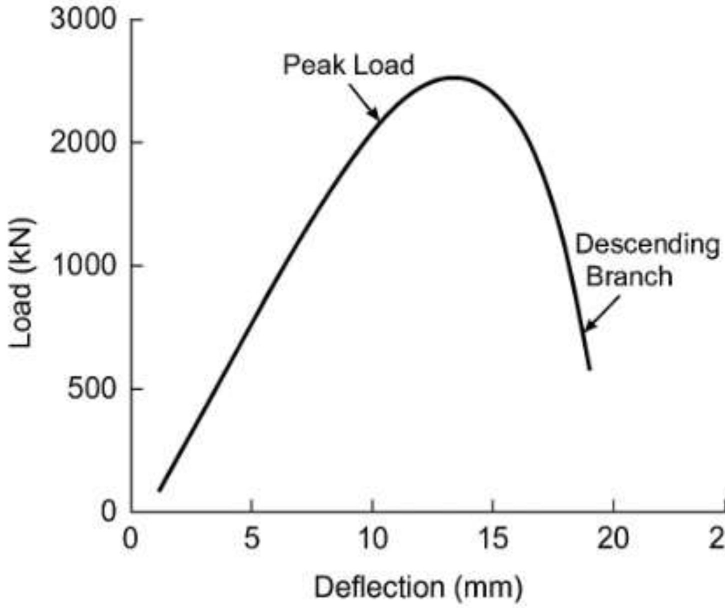

Figure 4.2 Load–Deflection Curve for SCC Columns Under Axial Load

Table 2. Comparison of Mechanical Properties: SCC vs. Conventional Concrete

Property	SCC	Conventional Concrete
Compressive Strength	Equal or higher	Standard

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Tensile Strength	Comparable or slightly reduced	Standard
Modulus of Elasticity	Slightly lower	Higher
Bond Strength	Higher	Standard
Shrinkage & Creep	Higher risk	Moderate

5. Durability Performance of SCC

Durability is a major advantage of SCC, attributed to its dense microstructure and reduced voids due to self-compaction. SCC demonstrates lower permeability, higher resistance to chloride penetration, and improved sulphate resistance (Persson, 2001). The incorporation of SCMs further enhances durability by refining pore structure. Studies have reported improved freeze-thaw resistance and reduced carbonation depth when SCC is appropriately cured (Safiuddin et al., 2011). However, SCC's sensitivity to high paste volume can increase autogenous shrinkage, potentially leading to cracking if not controlled through fibres or shrinkage-reducing admixtures (Kovler & Roussel, 2011). Durability performance greatly influences long-term structural applications such as bridge decks, marine structures, and high-rise buildings where SCC has demonstrated superior performance.

6. Structural Behaviour of SCC in Beams, Columns and Slabs

6.1 Beams

SCC beams typically show enhanced shear behaviour due to better aggregate distribution and improved bond interaction (Benaicha et al., 2015). Flexural capacity remains comparable to vibrated concrete, though deflection behaviour may differ slightly due to variations in modulus of elasticity.

6.2 Columns

Due to high workability, SCC ensures excellent compaction in congested columns, leading to improved axial load capacity and reduced variability (Asteris et al., 2016). Higher bond and uniformity improve ductility, making SCC suitable for seismic applications.

6.3 Slabs and Precast Elements

SCC improves surface finish and reduces defects in precast slabs, walls, and architectural panels. The reduced need for vibration minimizes labour and accelerates production cycles.

7. SCC in Special Structural Applications

7.1 Precast and Prestressed Construction

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SCC significantly enhances the performance and production speed of precast members due to its flow uniformity and surface finishing quality (Kim et al., 2010).

7.2 Repair and Rehabilitation

Owing to its excellent filling ability, SCC is widely used in repair works for jacketing, encasements, and retrofitting of deteriorated elements (Safiuddin et al., 2011).

7.3 Fibre-Reinforced SCC (FR-SCC)

The incorporation of steel, glass, polypropylene, or basalt fibres improves ductility, toughness, and crack resistance, making SCC suitable for seismic retrofitting and industrial floors (Ferrara et al., 2007).

8. Challenges and Limitations of SCC

Despite its advantages, SCC presents practical limitations, including sensitivity to moisture variation, dependency on chemical admixtures, higher cost, and risk of segregation when improperly designed (Domone, 2007). Increased autogenous shrinkage and creep may impact long-term performance. Ensuring consistency in batching and mixing remains a challenge in large-scale projects. Quality control procedures such as regular slump-flow and V-funnel testing must be enforced at site conditions.

9. Sustainable and Future Trends in SCC Research

Recent research focuses on sustainable SCC using industrial by-products such as fly ash, slag, waste glass powder, quarry dust, and nano-silica to reduce carbon emissions (Memon et al., 2012). Innovations in self-healing SCC, nano-modified SCC, and bio-based admixtures show potential for improving durability and structural behaviour. Digital fabrication methods such as 3D-printed SCC and automated placement technologies will shape the future of high-performance concrete construction.

10. Conclusion

Self-Compacting Concrete represents a transformative material in structural engineering due to its excellent fresh and hardened properties, superior durability, and enhanced structural performance. Its ability to flow and compact without mechanical vibration improves construction quality, especially in heavily reinforced and complex structural elements. The reviewed literature confirms SCC's suitability for beams, columns, slabs, precast members, and repair applications, while identifying challenges related to mix sensitivity, shrinkage, and

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field control. Continued research into sustainable materials, fibre reinforcement, nano-modification, and automated systems will advance SCC's role in future infrastructure.

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