PROGRESS AND INNOVATIONS IN CONCRETE TECHNOLOGY: A LITERATURE REVIEW

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Abstract

Concrete technology has undergone significant evolution over the past several decades due to increasing demands for durability, sustainability, and performance. Advances in material science, chemical admixtures, supplementary cementitious materials, and construction techniques have led to the development of high-performance and special concretes. The review covers fundamental properties of concrete, advances in cement and aggregates, supplementary cementitious materials, chemical admixtures, high-performance concrete, self-compacting concrete, fiber-reinforced concrete, durability issues, and sustainable concrete technologies. The study highlights key findings, trends, and research gaps in concrete technology.

Keywords: Concrete technology, cement, admixtures, high-performance concrete, durability, sustainable concrete

1. INTRODUCTION

Concrete is the most widely used construction material in the world due to its versatility, availability of raw materials, and relatively low cost. Traditional concrete, while adequate for many applications, exhibits limitations such as low tensile strength, susceptibility to cracking and durability issues under aggressive environments. Consequently, extensive research has been carried out to improve the performance, durability, and sustainability of concrete.

Concrete technology encompasses the study of materials, mix design, production, placement, curing, and performance of concrete. Significant advancements were reported in the areas of high-performance concrete, self-compacting concrete, fiber-reinforced concrete, and environmentally sustainable alternatives. This survey aims to summarize and critically review these developments.

2. CEMENT AND CEMENTITIOUS MATERIALS

2.1 Ordinary Portland Cement (OPC)

Ordinary Portland cement remains the primary binding material in concrete. Studies have focused on hydration mechanisms, microstructure development, and strength gain. Research emphasized optimizing clinker composition to improve early strength and reduce energy consumption.

2.2 Blended Cements

Blended cements incorporating fly ash, slag, and limestone have been extensively studied. Literature reports that blended cements improve durability reduce heat of hydration, and lower CO_2 emissions compared to OPC.

3. AGGREGATES IN CONCRETE

- Aggregates constitute approximately 60–75% of concrete volume.
- Aggregate size, shape, and texture effects on workability and strength
- Use of recycled aggregates from construction and demolition waste
- Performance of lightweight aggregates in structural and non-structural concrete
- Studies concluded that proper grading and quality control of aggregates significantly influence concrete performance.

4. SUPPLEMENTARY CEMENTITIOUS MATERIALS (SCMS)

SCMs have been widely researched for improving concrete properties and sustainability.

4.1 Fly Ash

Fly ash improves workability, long-term strength, and resistance to sulfate attack. Class F fly ash is particularly effective in enhancing durability.

4.2 Ground Granulated Blast Furnace Slag (GGBS)

GGBS contributes to reduced permeability and improved resistance to chemical attack. Literature reports enhanced long-term strength but slower early-age strength development.

4.3 Silica Fume

Silica fume significantly increases compressive strength and reduces permeability. It is commonly used in high-performance concrete.

5. CHEMICAL ADMIXTURES

Chemical admixtures have played a critical role in modern concrete technology.

5.1 Water-Reducing and Superplasticizers

High-range water reducers based on sulfonated naphthalene and polycarboxylate ethers enable low water–cement ratios, improving strength and durability.

5.2 Air-Entraining Admixtures

These admixtures enhance freeze–thaw resistance by creating microscopic air bubbles within the concrete matrix.

6. HIGH-PERFORMANCE AND SPECIAL CONCRETES

6.1 High-Performance Concrete (HPC)

HPC is characterized by high strength, low permeability, and enhanced durability. Literature emphasizes optimized mix design using SCMs and superplasticizers.

6.2 Self-Compacting Concrete (SCC)

SCC flows under its own weight without vibration. Research highlights improved construction efficiency and surface finish.

6.3 Fiber-Reinforced Concrete (FRC)

Steel, glass, synthetic, and natural fibers improve tensile strength, ductility, and crack resistance. Hybrid fiber systems show superior performance.

7. DURABILITY OF CONCRETE

Durability has been a major research focus due to infrastructure deterioration.

7.1 Chemical Attack

Studies on sulfate attack, acid attack, and chloride-induced corrosion emphasize the role of low permeability and SCMs.

7.2 Carbonation

Carbonation depth is influenced by water–cement ratio, curing conditions, and environmental exposure.

7.3 Alkali–Silica Reaction (ASR)

Use of low-alkali cement and SCMs has been found effective in mitigating ASR.

8. SUSTAINABLE AND GREEN CONCRETE

- Sustainability concerns have driven research toward:
- Reduction of cement content
- Use of industrial by-products
- Geopolymer concrete

Geopolymer concrete, based on alumino-silicate materials, shows promise in reducing carbon emissions while maintaining adequate mechanical properties.

9. RESEARCH GAPS AND FUTURE TRENDS

- Despite significant progress, literature identifies several research gaps:

- Long-term field performance of novel concretes
- Standardization of sustainable concrete materials
- Life-cycle assessment and durability-based design
- Future research is expected to focus on nano-materials, digital mix optimization, and carbon-neutral concrete.

10. CONCLUSION

Advances in cement chemistry, admixtures, SCMs, and special concretes have significantly enhanced concrete performance and sustainability. Continued research is essential to address durability challenges and environmental impacts associated with concrete production.

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