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Study of Mix Design of Self Compacting Concrete on M-30 Grade

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Abstract: Self-compacting concrete (SCC) has gained significant attention in recent years due to its ability to flow under its own weight without the need for mechanical compaction. This study presents an investigation into the mix design of M-30 grade self-compacting concrete, with a focus on optimizing workability, compressive strength, and durability characteristics. Various combinations of binder content, aggregates, and admixtures were considered to develop a cost-effective and efficient SCC mix. The influence of water-powder ratio, superplasticizer dosage, and fine-to-coarse aggregate ratio on the properties of SCC, such as filling ability, passing ability, and segregation resistance, were studied. The experimental results revealed an optimal mix design that satisfies the requirements of fresh and hardened properties, ensuring suitable performance for structural applications. The developed mix design also demonstrated potential for enhancing the sustainability of concrete by incorporating supplementary cementitious materials.

Keywords: Self-compacting concrete, M-30 grade, mix design, workability, compressive strength, superplasticizer, sustainability, supplementary cementitious materials.

INTRODUCTION

Self-compacting concrete (SCC) represents a significant advancement in concrete technology, offering numerous benefits over conventional vibrated concrete. First introduced in the late 1980s in Japan, SCC is designed to flow and compact under its own weight without the need for mechanical vibration, making it highly effective in situations with congested reinforcement, complex formworks, and for improving the quality and efficiency of construction. The elimination of mechanical compaction results not only in labor savings but also ensures a homogeneous and defect-free finished product, which can significantly enhance the durability and structural integrity of concrete structures.

The mix design of SCC is crucial, as it needs to achieve a delicate balance between its fresh and hardened properties. For an effective SCC mix, properties such as filling ability, passing ability, and segregation resistance are critical in the fresh state, while strength and durability are key considerations in the hardened state. The success of SCC lies in the proper selection and proportioning of its constituents, which typically include cement, aggregates, water, mineral admixtures, and chemical admixtures like superplasticizers and viscosity-modifying agents (VMAs). Achieving the desired balance often involves optimizing these components to ensure good workability without compromising on strength and stability.

The M-30 grade SCC is especially popular for medium-strength applications, striking a good balance between cost and performance, suitable for a variety of structural applications in buildings and infrastructure. The current study aims to develop a mix design for M-30 grade SCC, focusing on the optimization of workability, compressive strength, and overall durability. By studying the effects of various mix parameters—including water-powder ratio, the dosage of superplasticizers, and fine-to-coarse aggregate ratios—on SCC's properties, the goal is to determine an optimal mix that not only meets performance requirements but also contributes to the sustainability of concrete production.

Furthermore, with the growing emphasis on sustainability, the incorporation of supplementary cementitious materials (SCMs), such as fly ash or slag, has become increasingly important. SCMs not only reduce the reliance on Portland cement, thereby reducing the carbon footprint, but also improve various properties of SCC, such as flowability, resistance to cracking, and long-term durability. This paper investigates how the strategic incorporation of these SCMs can enhance the properties of M-30 SCC, making it an eco-friendly and high-performance choice for construction.

The study provides an in-depth analysis of the mix design methodology, aiming to provide practitioners with practical guidelines for the effective use of SCC in medium-strength structural applications. The findings are expected to contribute to the efficient application of SCC in the construction industry, enhancing quality, productivity, and sustainability in concrete construction.

LITERATURE REVIEW

Self-compacting concrete (SCC) has been widely studied and developed since its inception in Japan during the late 1980s. Its ability to flow under its own weight without the need for mechanical compaction has made SCC an innovative solution for overcoming challenges related to congested reinforcement, complex formworks, and labor-intensive practices in concrete construction. This literature review aims to summarize key research advancements related to the mix design and performance characteristics of M-30 grade SCC, with a specific focus on workability, compressive strength, durability, and sustainability.

Development and Properties of Self-Compacting Concrete

Okamura and Ouchi (2003) were among the pioneers who laid the foundation for SCC technology. Their studies emphasized the need for a concrete mix that could achieve both high flowability and segregation resistance, making it ideal for complex structural elements. This early research identified the key properties of fresh SCC: filling ability, passing ability, and segregation resistance. Numerous studies (e.g., EFNARC, 2002) have since outlined guidelines and specifications for achieving these fresh properties, emphasizing the importance of precise control over mix constituents such as binder content, water-powder ratio, and superplasticizers.

Mix Design Approaches for SCC

The mix design of SCC is a challenging task that requires a balanced approach between different components, including cement, aggregates, water, mineral admixtures, and chemical admixtures. Hossain and Lachemi (2010) explored various mix design methodologies for SCC, highlighting the importance of fine aggregates and mineral admixtures like fly ash or slag. The use of superplasticizers and viscosity-modifying agents (VMAs) has been shown to play a key role in improving the flowability of SCC without causing segregation (Khayat, 1999). Several studies have also demonstrated the effectiveness of varying the water-to-powder ratio to achieve the desired balance between workability and strength (Grünewald and Walraven, 2001).

Performance Characteristics of M-30 Grade SCC

For medium-strength applications, M-30 grade SCC provides a good compromise between cost, workability, and strength. Several studies (Dehn et al., 2000; Persson, 2001) have shown that SCC can achieve comparable or even better compressive strength compared to traditional vibrated concrete. The key challenge, however, is achieving the desired performance without mechanical compaction. This has led to numerous experiments on optimizing aggregate size distribution, superplasticizer dosage, and the use of SCMs (Aggarwal et al., 2008). It has been found that by adjusting the fine-to-coarse aggregate ratio and incorporating mineral admixtures, the rheological properties of SCC can be significantly improved, thus ensuring better flowability and uniformity in M-30 grade mixes.

Durability and Sustainability Considerations

Durability is a key aspect of SCC, particularly in ensuring the long-term performance of structures subjected to aggressive environments. Studies by Nanthagopalan and Santhanam (2011) have demonstrated that the incorporation of supplementary cementitious materials (SCMs) like fly ash and slag can significantly improve the durability of SCC by reducing porosity and enhancing resistance to chloride penetration. In addition, these SCMs contribute to sustainability by partially replacing Portland cement, which helps in reducing the carbon footprint associated with concrete production (Mehta, 2004).

Environmental concerns have increasingly prompted research into the development of sustainable SCC mixtures. Incorporating SCMs not only reduces the consumption of cement but also improves certain properties of SCC, such as reducing the heat of hydration and enhancing long-term strength and durability. Researchers like Siddique (2011) have reported that fly ash, in particular, enhances the rheological properties of SCC while also making it more eco-friendly, which is crucial in the context of sustainable construction practices.

Challenges and Gaps in Existing Research
Despite the progress made, challenges remain in optimizing the mix design of SCC, especially for M-30 grade concrete used in medium-strength structural applications. One of the ongoing issues is achieving a balance between workability and stability without incurring high material costs. Studies such as those by Domone (2006) highlight the complexity involved in the mix design process, emphasizing that empirical approaches often lead to non-optimal solutions. Additionally, the performance of SCC in terms of its mechanical properties under varying environmental conditions and its long-term durability needs further in-depth analysis. There is also a need for more extensive research on the incorporation of locally available waste materials as SCMs to enhance both the sustainability and cost-effectiveness of SCC.

METHODOLOGY

1. Materials Used

- Cement: Ordinary Portland Cement (OPC) 43 grade.
- Aggregates: Fine aggregates (river sand, Zone II) and coarse aggregates (crushed granite, 10 mm max size).
- SCMs: Fly ash (Class F) and GGBS used for partial cement replacement.
- Chemical Admixtures: Polycarboxylate ether (PCE) superplasticizer and viscosity-modifying agent (VMA).
- Water: Potable water for mixing and curing.

2. Mix Design Procedure

- Target Mix: M-30 grade with a target mean strength of 38 MPa.
- Water-Powder Ratio: 0.40 to 0.45 to balance workability and strength.
- Superplasticizer Dosage: Varied from 1% to 2% by weight of binder.
- SCM Incorporation: Fly ash and GGBS used at 10-25% replacement levels to enhance workability, strength, and sustainability.

3. Testing Methods

- Fresh Properties: Slump flow (600-750 mm), T500 (flow time), V-funnel (flow rate), L-box (passing ability), and J-ring (segregation resistance).
- Hardened Properties: Compressive strength (tested at 7, 14, and 28 days) and splitting tensile strength (28 days).

Tests Conducted:
Mix Proportion:

Cement	Sand	CA	Water
495.50kg	777.69KG	812.80KG	198.00
1	1.57	1.64	0.40

Now convert into SCC Proportions

Cement = 495.50 kg
Sand =777.69 kg
C. aggregate = 812.80 kg
Total aggregate (T.A)= 777.69 +812.80 =1592.00

ADOPT 55% of T.A as F.A

Fine aggregate =1592.00 * 0.55 =876.01 kg/ m^3
Coarse aggregate =715.58 kg/ m^3

Now the Modified proportion becomes:-

Cement	Sand	CA	Water
495.00Kg	876.01Kg	715.58Kg	198.00
1	1.76	1.44	0.40

FRESH CONCRETE PROPERTIES:

Trail mix	Slump Flow		V-Funnel		L-Box
	Mm	T_{50}(Sec)	T_0(Sec)	T_5(Sec)	H_2/H_1
A	670	5.0	11	13	0.80
B	675	4.5	10	12	0.82
C	685	3.5	8	9	0.84
FINAL	680	4.0	9	11	0.83

HARDENED CONCRETE PROPERTIES

Trail Mix	Compressive Strength (N/mm^2)				Tensile Strength (N/mm^2)	
	1 day	3 days	7 days	28 day	7 days	28 days
A	18.5	22.0	30.5	42.0	2.542	3.108
B	18.0	22.0	30.0	41.0	2.386	3.264
C	16.0	20.5	28.5	39.0	2.392	2.929
Final Mix	17.0	20.0	26.5	40.0	2.312	3.607

CONCLUSIONS

After conducting a thorough investigation into the behavior of Self-Compacting Concrete (SCC), the following conclusions were reached:

1. Since there are no specific standardized procedures for the mix design of SCC, the study's mix designs were developed following Indian Standards, incorporating necessary adjustments to meet guidelines from various institutions and studies.
2. Trial mixes were prepared to ensure self-compaction, flowability, and segregation resistance.

The results for the final mix are as follows:

- Compressive strength at 1 day: 17.0 N/mm^2
- Compressive strength at 3 days: 20.0 N/mm^2
- Compressive strength at 7 days: 26.5 N/mm^2
- Compressive strength at 28 days: 40.0 N/mm^2
- Tensile strength at 7 days: 2.312 N/mm^2
- Tensile strength at 28 days: 3.607 N/mm^2

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