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Strength and Durability Assessment of Prestressed Precast Self Compacting Concrete of Beams

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Abstract

This study evaluates the strength and durability of prestressed, precast self-compacting concrete (SCC) beams of M45 grade. Prestressing enhances load resistance and crack control, while precasting ensures quality and accelerates construction. SCC improves workability and compaction without vibration. Identical beam specimens (200 mm × 200 mm × 700 mm) and concrete cubes were cast and cured for 28 days, then tested for compressive strength, flexural strength, durability, and water absorption. Results confirm that SCC with prestressing and precasting offers superior environmental resistance and construction efficiency, providing valuable insights for durable infrastructure development.

INTRODUCTION

Concrete remains essential in modern infrastructure due to its strength, durability, and versatility. Advancements in prestressing, precasting, and self-compacting concrete (SCC) enhance structural performance, efficiency, and sustainability. Prestressing improves load-bearing capacity and crack resistance, precasting ensures quality and faster construction, while SCC offers superior workability and durability without vibration.

This study evaluates the strength and durability of prestressed precast SCC beams compared to conventional prestressed precast beams. Key parameters such as compressive strength, flexural strength, and environmental resistance are analyzed. Findings provide insights into SCC's advantages in enhancing durability, construction speed, and structural efficiency for high-demand infrastructure projects.

LITERATURE REVIEW

1. **Shiraz Tayabji and Dan Ye (2001) [1]** carried out experimental work on precast concrete pavements and suggested that precast concrete pavements were durable and also reduced the cost of panel fabrication and installation.
2. **Rajagopalan N. (2005)** [2] conducted studies on the use of precast concrete systems in India, highlighting that the use of precast technology in pavements has significantly improved construction speed while maintaining structural integrity and durability, making it suitable for urban infrastructure.
3**. R. Srinivasan and S. Sathiya (2010)** [3] performed a study on self-compacting concrete (SCC) with fly ash, concluding that the addition of

fly ash improved the flowability of the mix and enhanced its long-term strength and durability, especially in high-strength applications like prestressed precast systems.

4. **Rao, G. A., and Kumar, V. (2007)** [4] explored the performance of SCC in precast applications in India, demonstrating that SCC showed better resistance to chloride penetration and crack formation compared to conventional concrete, which makes it a more durable option for prestressed precast beams.

5. **Gambhir, M.L. (2013)** [5] emphasized in his research on the strength characteristics of prestressed concrete that incorporating high-strength prestressed tendons into precast concrete enhances the overall load-bearing capacity, and the use of SCC further optimizes the structural performance by eliminating voids and ensuring uniform distribution.

6. **Sharma, A. and Bansal, P. (2015)** [6] investigated the use of supplementary cementitious materials in precast concrete and found that the inclusion of GGBS and fly ash in SCC mixes not only improved workability but also significantly enhanced the durability of precast components exposed to aggressive environments.

7. **Sinha, R. and Roy, D. (2017)** [7] evaluated the use of SCC in bridge girders in Indian conditions, showing that SCC with optimized superplasticizer content reduced the need for vibration during casting, resulting in higher durability and reduced production time for precast prestressed beams.

METHODOLOGY

The methodology for this research will involve several key steps aimed at comparing the strength and durability of prestressed precast self-compacting concrete (SCC) beams against prestressed precast conventional concrete beams.

1. Specimen Preparation:

3 cubes of prestressed precast SCC and 3 cubes of prestressed precast conventional concrete casted for compressive strength for 28 days of curing.

Three beam specimens prepared using standardized dimensions. The beams included:

- Prestressed Precast Self-Compacting Concrete (PPSCC) beams.
- Prestressed Precast Conventional Concrete beams (PPCC).

High-strength steel tendons with a consistent pretensioning force were used for both sets of specimens.

2. Mix Design:

- **SCC Mix**: A specific mix incorporating supplementary cementitious materials (e.g., fly ash, GGBS) was used to achieve self-compaction properties, improving flowability without compromising strength.
- **Conventional Concrete Mix**: A traditional mix design was adopted, with appropriate vibration to ensure compaction.

3. Curing:

All cubes were cured for 28 days to ensure proper compressive strength development. Additionally, two beam specimens of PPSCC and two beam specimens of PPCC were cured for 28 days to assess flexural strength, while one specimen from each category was cured for 90 days.

Durability Tests:

Water Absorption Test: To measure the water permeability of the beams and assess their durability against moisture ingress.

Flexural Strength Test: Conducted on beam specimens using a standard UTM Machine of 10000 KN. This test measured the flexural strength and the load-bearing capacity of the beams.

Ultrasonic Pulse Velocity Test: To check for internal defects such as cracks and voids within the concrete.

The Rebound Hammer Test, also known as the Schmidt Hammer Test, is a widely used non-destructive testing (NDT) method for assessing the surface hardness and estimating the compressive strength of concrete. It provides a quick and practical means of evaluating in-situ concrete without causing damage to the structure. The test is based on the principle that the rebound of a spring-loaded mass is proportional to the surface hardness of the material.

4. Data Analysis:

- The results from the compressive strength test, flexural strength test, and durability tests were analyzed to compare the performance of prestressed precast SCC and conventional concrete beams.
- Parameters such as compressive strength, flexural strength, maximum load and deflection were evaluated to determine which material provides better structural performance and long-term durability.

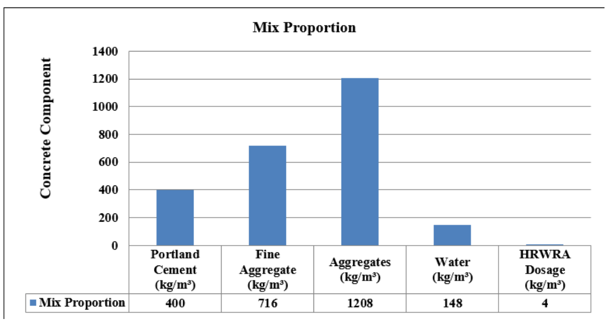
RESULT AND DISCUSSIONS

Table 1: Mix Proportions for Prestressed Precast SCC Beam (M45)

[Mix Proportion Ratio:1:1.79:3.02]

Concrete Component	Mix Proportion
Portland Cement (kg/m^3)	400
Fine Aggregate (kg/m^3)	716
Aggregates (kg/m^3)	1208
Water (kg/m^3)	148
HRWRA Dosage (kg/m^3)	4

Table 1 shows the mix proportions for prestressed precast self-compacting concrete (SCC) beam designed for M45 grade. The detailed breakdown of each component highlights the mix's composition and performance characteristics.

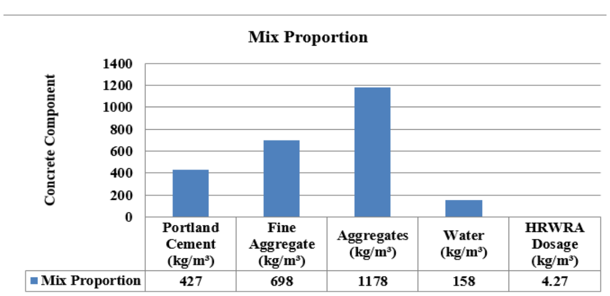


Graph No.1: Mix Proportions for Prestressed Precast SCC Beam (M45)

Table 2: Mix Proportions for Prestressed Precast CCP Beam (M45)

Mix Proportion Ratio:1:1.63:2.76

Concrete Component	Mix Proportion
Portland Cement (kg/m^3)	427
Fine Aggregate (kg/m^3)	698
Aggregates (kg/m^3)	1178
Water (kg/m^3)	158
HRWRA Dosage (kg/m^3)	4.27

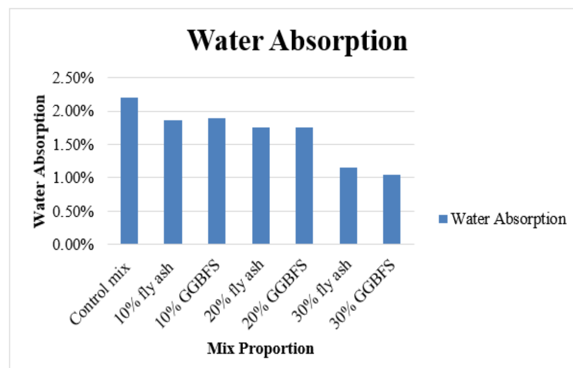


Graph No.2: Mix Proportions for Prestressed Precast CCP Beam (M45)

Water Absorption: Water absorption in concrete refers to the process by which concrete absorbs water when immersed, indicating its porosity and permeability. This property significantly influences the durability and strength of concrete structures. Lower water absorption typically correlates with higher durability and resistance to environmental factors.

Table No. 3 Water Absorption Test Results

Mix Proportion	Water Absorption (%)
Control mix	2.20
10% fly ash	1.86
10% GGBFS	1.90
20% fly ash	1.75
20% GGBFS	1.76
30% fly ash	1.15
30% GGBFS	1.05



Graph No: 3: Water Absorption

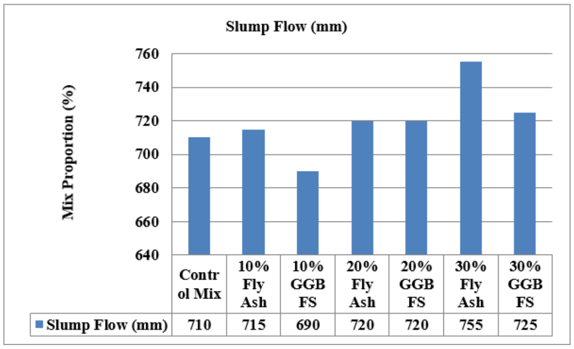
Fresh Properties of Self-Compacting Concrete (SCC):

The Fresh Properties of **SCC** Are Key Indicators of Its Workability, Ease of Placement, And Ability To Fully Fill Molds Without The Need For Mechanical Vibration. For **SCC** Beams, The Following Fresh Properties Are Typically Assessed.

Table No. 4 Fresh Properties of Self-Compacting Concrete Test

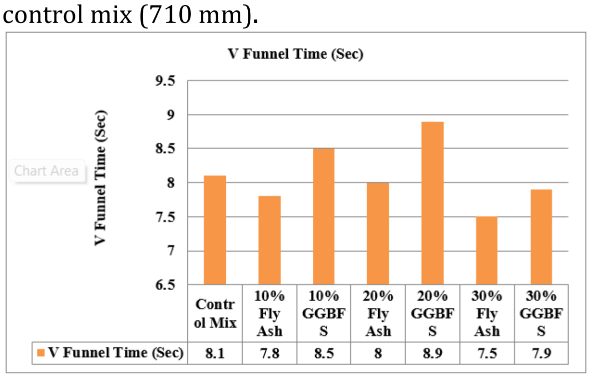
Mix Proportion (%)	Slump Flow (mm)	V Funnel Time (Sec)	L-Box Ratio
Control Mix	710	8.1	0.79
10% Fly Ash	715	7.8	0.85
10% GGBFS	690	8.5	0.82
20% Fly Ash	720	8.0	0.86
20% GGBFS	720	8.9	0.85

30% Fly Ash	**755**	**7.5**	**0.88**
30% GGBFS	725	7.9	0.85



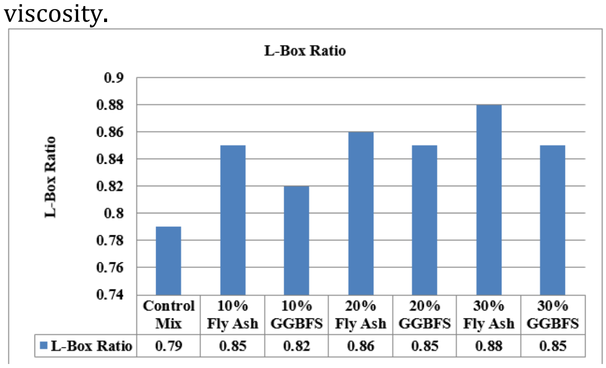
Graph No:4: Slump Flow (mm)

The **slump flow** values indicate that **30% Fly Ash** achieved the highest flowability (755 mm), suggesting improved workability compared to the control mix (710 mm).



Graph No: 5: V Funnel Time (Sec)

The **fastest flow time** (highest workability) was observed in **30% Fly Ash** (7.5 sec), indicating enhanced self-compacting properties. The **longest flow time** (poorest flowability) was noted in **20% GGBFS** (8.9 sec), showing a slight increase in viscosity.



Graph No: 6: L-Box Ratio

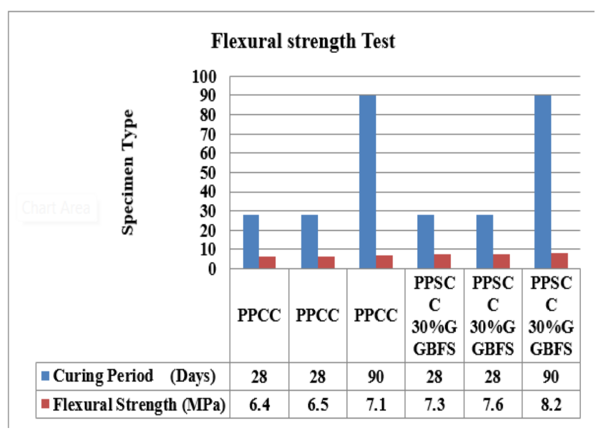
30% Fly Ash exhibited the highest L-Box ratio (0.88), indicating superior passing ability and minimal obstruction. The control mix had the lowest L-Box ratio (0.79), suggesting higher resistance to flow around obstructions.

Flexural strength:

An important property to assess in prestressed precast self-compacting concrete **(SCC)** beams. It measures the beam's ability to resist bending under external loads, which is critical for structural integrity, especially for beams subjected to bending moments, such as in bridges, floors, and other civil engineering structures.

Table No.5: Flexural strength Test

Specimen Type	**Curing Period (Days)**	**Flexural Strength (MPa)**	**Remark**
PPCC	28	6.4	Consistent Performance
PPCC	28	6.5	Good Flexural Capacity
PPCC	90	7.1	Improved After 90 Days
PPSCC 30%GGBFS	28	7.3	Good Flexural Capacity
PPSCC 30%GGBFS	28	7.6	Slightly Higher Than Average
PPSCC 30%GGBFS	**90**	**8.2**	**Increased With Curing Time**



Graph No: 7: Flexural strength Test

Ultrasonic Pulse Velocity (UPV) Test: The UPV test involves measuring the velocity of ultrasonic waves passing through concrete to evaluate its quality, uniformity, and detect internal flaws such as cracks, voids, or honeycombing. Higher pulse velocities typically indicate better quality concrete with fewer defects.

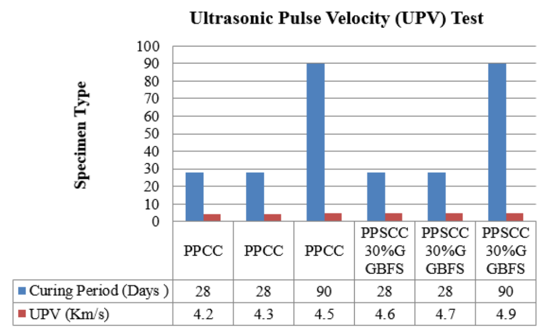
Table No.6: Ultrasonic Pulse Velocity (UPV) Test

Specimen Type	Curing Period (Days)	UPV (Km/s)	Concrete Quality	Remarks
PPCC	28	4.2	Good.	Slightly Lower Upv
PPCC	28	4.3	Good	Satisfactory
PPCC	90	4.5	Excellent	Improved Over Type
PPSCC 30%GGBFS	28	4.6	Good	High Homogeneity
PPSCC 30%GGBFS	28	**4.7**	Excellent	Consistent Result
PPSCC 30%GGBFS	**90**	**4.9**	Excellent	Improved Density

Table 7: A: Concrete Quality Based on UPV Values

According to IS: 516 (Part 5, Sec- 1), the UPV test results are as follows:

UPV (Km/s)	Concrete Quality	Remarks
Above 4.5	Excellent	Homogeneous, dense concrete
3.5 – 4.5	Good	No significant voids or cracks
3.– 3.5	Medium	Minor voids or reduced quality
Below 3.0	Doubtful	Cracks, voids, or poor compaction



Graph No: 8: Ultrasonic Pulse Velocity (UPV) Test

Rebound Hammer Test: The Rebound Hammer Test (also known as the Schmidt Hammer Test) is a non-destructive method commonly used for estimating the compressive strength of concrete. It works by measuring the rebound of a spring-loaded hammer that strikes the surface of the concrete, providing an indirect indication of the concrete's hardness, which correlates to its strength.

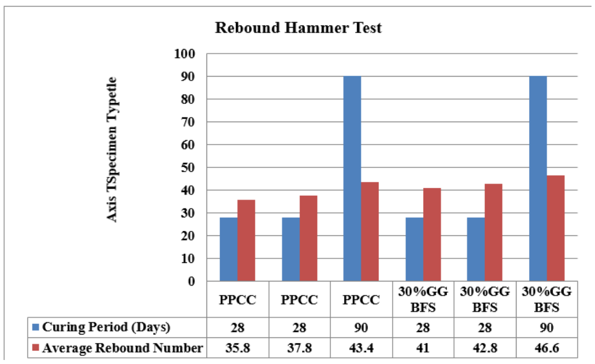
Table No.8: Rebound Hammer Test

Specimen Type	Curing Period (Days)	Red1	Red 2	Red 3	Red 4	Red 5	Average Rebound Number	Quality Of Concrete
PPCC	28	35	36	37	35	36	35.8	Medium (Slightly Lower)
PPCC	28	37	38	39	38	37	37.8	Medium (Good Surface Quality)
PPCC	90	42	43	45	44	43	43.4	High (Significant Improvement)
PPSCC 30%GGBFS	28	39	41	40	42	43	41.0	Medium (Satisfactory)
PPSCC 30%GGBFS	28	42	43	44	43	42	42.8	High (Consistent Surface)
PPSCC	90	45	46	47	48	47	**46.6**	Very High

30%GGBFS								(Improved Hardness)

Table 9: A: Table shows that the average Rebound Number and the quality of Concrete:

Average Rebound Number	Quality of Concrete
> 40	Very Good hard layer
30 – 40	Good layer
20 – 30	Fair
< 20	Poor concrete
0	Delaminated



Graph No: 9: Rebound Hammer Test

CONCLUSION

Water absorption:

Water absorption decreased with fly ash and GGBFS incorporation, with 30% GGBFS (1.05%) showing the best performance. GGBFS mixes exhibited lower absorption than fly ash mixes, enhancing concrete durability.

Fresh Properties of Self-Compacting Concrete (SCC):

Workability improved with fly ash and GGBFS, with 30% fly ash achieving the highest slump flow (755 mm). Fly ash mixes showed better flowability, while both additives enhanced passing ability and stability.

Flexural Strength:

PPSCC (30% GGBFS) showed higher flexural strength than PPCC, with strength improving over time. At 90 days, PPSCC reached 8.2 MPa, demonstrating superior long-term performance.

Ultrasonic Pulse Velocity (UPV) Test:

PPSCC (30% GGBFS) exhibited higher UPV values (4.6–4.9 km/s) than PPCC (4.2–4.5 km/s), indicating better concrete quality and density. UPV improved with curing time, with PPSCC reaching 4.9 km/s at 90 days, demonstrating higher homogeneity and durability.

Rebound Hammer Test:

PPSCC (30% GGBFS) exhibited higher rebound numbers than PPCC, indicating better surface hardness and concrete quality. At 90 days, PPSCC reached 46.6, showing significant improvement in hardness and durability compared to PPCC (43.4). These findings suggested that integrating these techniques results in high-performance beams suitable for durable and efficient construction applications.

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