A Performance Evaluation of Prestressed Concrete Beams and RCC Beams in Modern Construction in Structural Engineering

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Abstract - Prestressed concrete is a special type of reinforced concrete in which internal forces are intentionally created in advance, before the structure carries any external load. This is done by stretching high-strength steel tendons placed inside the concrete. The main aim of prestressing is to balance the tensile stresses that occur when the structure is loaded, which improves the overall behaviour of concrete. Since concrete performs well in compression but is weak in tension, compressive forces are introduced in advance so that the tensile stresses produced during use are reduced or completely removed. As a result, cracking is minimized, the load-carrying capacity increases, deflection decreases, and durability improves.

In post-tensioning, high-strength steel strands or bars are used as reinforcement. Strands are commonly applied in horizontal members such as slabs, beams, foundations, and bridges, whereas bars are mostly used in vertical members like columns and walls. A typical post-tensioning steel strand has a tensile strength of around 1860 N/mm², which is much higher than that of ordinary reinforcing steel (rebar), whose tensile strength is usually about 600 N/mm². During this project, we carefully observed and studied different site operations related to post-tensioned beams. We also examined the various tendon diameters and types used to apply prestressing forces in the structure.

For this project, M40 grade concrete was used. Ultrafine Slag was added as a partial replacement for cement by weight in the concrete mix. The prestressing operation was carried out after seven days, when the concrete reached a strength of approximately 25 N/mm². A prestressing power pack along with a mono-strand stressing jack was used to perform the stressing process. When the tendons are pulled, they try to return to their original length, but they are held in place by anchorages.

A comparison was also made between post-tensioned members and conventional reinforced cement concrete (RCC) members of the same span, including a detailed cost analysis. Through this project, we also learned important aspects of professional construction practices and site management.

Keywords: Concrete, Ultrafine Slag, Prestressed Concrete, Post-Tensioning, Tendons, Grouting.

1.INTRODUCTION

Concrete is one of the most widely used construction materials because of its strength, durability, flexibility, and low cost. It is made by mixing cement, sand, coarse aggregates like gravel, and water. When water is added, a chemical reaction called hydration occurs, which hardens the mixture into a solid mass. The quality of concrete depends on proper materials, correct proportions, good mixing, placement, compaction, and curing. It is commonly used in buildings, bridges, roads, dams, and tunnels. Since concrete is strong in compression but weak in tension, steel reinforcement is added to form reinforced cement concrete (RCC), which improves its tensile strength. In India, concrete design is generally done as per IS 456:2000. Concrete is available in different types such as normal strength, high strength, self-compacting, fiber-reinforced, and high-performance concrete. Its properties can be improved by adding materials like fly ash and silica fume. Fresh concrete is tested for workability using slump and compaction tests, while hardened concrete is tested for strength, usually at 7, 14, and 28 days. Proper design and quality control ensure safe and durable structures.

1.4 Prestressed concrete

Prestressed concrete, as defined in IS 1343:2012, is a type of concrete in which internal compressive stresses are introduced by tensioning high-strength steel tendons to counteract tensile stresses caused by external loads. Since concrete is weak in tension, this method helps improve its performance by reducing cracks and increasing load-carrying capacity. In prestressed concrete members like beams, slabs, and bridges, compressive stress is applied before the structure is put into service, which balances the tensile forces that occur during bending. Unlike reinforced concrete (RCC), which uses steel bars to resist tension after cracks develop, prestressed concrete prevents cracks by applying stress in advance. Prestressing can be done using methods such as pre-tensioning and post-tensioning, with either bonded or unbonded tendons.

This technique results in stronger, more durable, and efficient structures.

1.4.1 Need of Prestressed Concrete

Concrete is Strong in compression Weak in tension When a beam is subjected to loads. The bottom portion experiences tension The top portion experiences compression Because concrete cracks rapidly under tension, prestressing is done to apply the compressive stress in the tension zone before loading. This helps in preventing cracking and increasing load carrying capacity.

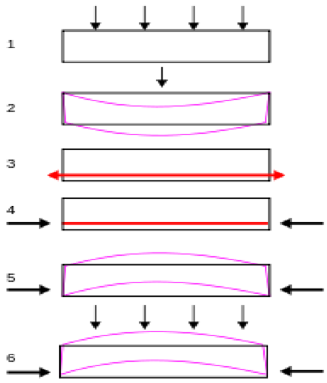

Diagram No: 1.4 Prestressed concrete

1.5 Objectives of the Work

- To assess the impact of Ultrafine Slag modified cement concrete on the strength and durability properties of both PSC and RCC beams using Ultrafine Slag 1203 as a supplementary cementitious material.
- To investigate the mechanical properties like compressive strength, flexural strength, load-deflection characteristics, and cracking pattern of beams.
- To Compare the structural performance of Prestressed Concrete (PSC) beams and Reinforced Cement Concrete (RCC) beams under similar loading conditions.
- To analyze serviceability characteristics like deflection control and crack width comparison between PSC and RCC beams.
- To compare material efficiency and structural economy between PSC and RCC beams.
- To confirm the experimental results with the provisions of the relevant Indian Standards like: IS 456:2000 (for RCC) and IS 1343:2012 (for PSC)
- To include professional construction practice experience

1.6 Scope of the Work

1. Preparation of control concrete mix and Ultrafine Slag-modified concrete mix is also included in the study.
2.The percentage replacement of cement with Ultrafine Slag will be chosen based on mix design suggestions (5-15%).
3.Experimental work will be conducted on: RCC beams and Prestressed concrete beams
4.The parameters considered for testing are: Compressive strength test, split Tensile Strength and Flexural strength test
5. Economic comparison will be restricted to material and construction cost analysis.

2.0 LITERATURE REVIEW

Mechanical and Durability Properties of Ultrafine Slag Modified Concrete:Authors P. Srinivasulu et al. (2025): The impact of partially substituting Ultrafine Slag 1203 for cement in concrete mixtures was examined in this study. Because of Ultrafine Slag's ultrafine particle size and latent hydraulic reaction, the author reported a significant improvement in early-age and 28-day compressive strength. Additionally, the study showed improved resistance to sulphate and chloride attack, decreased water permeability, and increased microstructural density. It was discovered that the ideal replacement level was between 10% and 15%, after which there were only slight Advatages.Chakravarthy et al. (2022):found that for M25 grade concrete, the maximum compressive strength was attained at 16% for both 7 and 28 days when cement was substituted with Ultrafine Slag at different percentages.

of 0%, 4%, 8%, 16%, 17%, 20%, 25%, 50%, 75%, and 100%. When combined with water, the cao found in Ultrafine Slag offers strong defense against acid and chemical attacks.

Ansari et al. (2021):revealed that for M70 grade concrete, fly ash and Ultrafine Slag were used in place of some of the cement. The compressive strength was 20% higher than that of regular concrete. Additionally, it was discovered that Ultrafine Slag produces higher strength than regular concrete and has a lower relative cost than cement for high strength concrete..

Comparative Study on Prestressed and Reinforced Concrete Beams Author: Almusallam (2019): This comparative research evaluated ultimate strength, deflection behavior, and cracking characteristics of prestressed and RCC beams. Prestressed beams demonstrated superior flexural performance, reduced crack widths, and improved serviceability compared to RCC beams designed as per IS 456:2000. The study concluded that prestressed concrete is more efficient for long-span and heavy-load applications.

High Strength Prestressed Concrete Beam Performance.Razvi et al.(2000): Surprising gains came through stronger concrete in prestressed beams. Shear resistance climbed when material strength went up. Structural behavior shifted favorably under load. Failure patterns changed, revealing new demands on design choices. Confinement mattered more than expected. Detailing of steel played a bigger role as stresses increased.

Design Provisions for Prestressed Concrete Members Reference Standard: IS 1343:2012.This standard provides guidelines for analysis, design, and construction of prestressed concrete structures. It specifies minimum concrete grades, permissible stresses, and serviceability requirements. The code emphasizes crack control, deflection limits, and durability considerations for prestressed beams.

Performance of High-Strength Prestressed Concrete Beams. Razvi et al. (1999): This research focused on the behavior of prestressed beams made with high-strength concrete. It was observed that higher

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concrete strength improved shear resistance and overall structural performance. The study also discussed failure modes and emphasized the importance of adequate confinement and reinforcement detailing.

2.4 Problem Statement

Modern construction requires materials that provide high strength, durability, fewer cracks, and better overall performance. Although prestressed concrete beams are structurally efficient and ultrafine slag improves the quality of concrete, their combined performance is not fully understood in real-world conditions. There is limited practical research on how ultrafine slag concrete behaves when used in prestressed systems. This study focuses on understanding how such concrete performs compared to conventional reinforced cement concrete, as small changes in materials can affect strength and behavior under load. It also considers long-term durability and how well these methods work on actual construction sites, since practical performance is just as important as laboratory results.

3.0 MATERIALS AND PRELIMINARY TESTS

3.2 Constituents of Concre

3.3.1.5Test Results of Cement

Tabulation No: 3.3.1.5Test Results of Cement

Test Results of Cement			
S.No	Characteristics	Test results	IS:12269-1897 specifications
1	Fineness (IS sieve No: 90 µm)	3.00%	<10%
2	Consistency	28%	-
3	Initial setting time (minutes)	35min	>30 minutes
4	Final setting time (minutes)	230min	<600 minutes
5	Specific gravity	3.14	3.15

3.3.2.4 Fine Aggregates Test Results

Tabulation No:3.3.2.4 Fine Aggregates Test Results

S.No	Property	Test results	IS:2386-1963 Specifications
1	Fineness modulus	2.7	-
2	Specific gravity	2.6	2.6 – 2.8
3	Water absorption	0.69%	-
4	Bulk density	1475kg/m^3(untrade	-
		1624kg/m^3(ridded)	-

3.3.3.4Coarse Aggregates Test Results

Tabulation No: 3.3.3.4 Coarse Aggregates Test Results

S.No	Property	Test results	IS:2386-1963 Specifications
1	Fineness modulus	3.53	-
2	Specific gravity	2.7	2.6-2.8
	Water Absorption (%)	0.80%	< 5.0
3	Abrasion test	34%	40%
4	Crushing value	22%	<30%
5	Bulk density	1483kg/m^3(untraded)	-
		1563kg/m^3(ridded)	-

3.3.4.3 Test results of Ultrafine Slag

Tabulation No:3.3.4.3 Test results of Ultrafine Slag

S.No	Property	Result	Standard Range
1	Sieve Analysis	93%	> 85%
2	specific gravity	2.72	2.6 – 2.8

3.40 Mix Design (M40)

Data

Grade of concrete = **M40**
Type of cement = OPC 53 Grade
Maximum aggregate size = 20 mm
Workability = 100 mm slump
Specific gravity:
Cement = 3.15
Fine aggregate = 2.65
Coarse aggregate = 2.70
Super plasticizer used

Test Result Data of Materials

1. Cement used : OPC 53 Grade conforming IS 12269
2. Specific gravity of cement : 3.15

Chemical admixture : Super Plasticizer conforming to IS 9103

4. Specific gravity of
   1) Coarse aggregate 20mm : 2.70
   2) Fine aggregate : 2.60
5. Water absorption:
   1) Coarse aggregate : 0.8 %
   2) Fine aggregate : 0.6 %

Sieve analysis:

1) Coarse aggregate: Conforming to all in aggregates of Table 2 of IS 383
2) Fine aggregate : Conforming to Grading Zone II of Table 4 of IS 383

Tabulation No:3.40 Concrete Mix Design (M40)

Materials	Cement	Fine aggregate	Coarse aggregate	Water	S.P
Kg/m^3	421	700	1180	160	4.2
Ratio	1	1.67	2.81	0.38	1

3.8 Experimental Investigation

3.8.1.1.1 Slump Cone Test Results

Tabulation No: 3.8.12 Slump Cone Test Results

S.No	Type of Concrete	Slump Value (mm)
1	Traditional Concrete	70 mm
2	Ultrafine Slag Concrete -1 (10 %)	66 mm
3	Ultrafine Slag Concrete -2 (15 %)	60 mm
4	Ultrafine Slag Concrete -3 (20 %)	63 mm

3.8.1.2.1 Test Results of Compaction Factor Test

Tabulation No: 3.8.1.2.1 Compaction Factor Test Result

S.No	Type of Concrete	Compaction
1	Traditional Concrete	0.87
2	Ultrafine Slag Concrete -1 (10 %)	0.9
3	Ultrafine Slag Concrete -2 (15 %)	0.95
4	Ultrafine Slag Concrete -3 (20 %)	0.9

3.8.2.1 Compressive strength test

Tabulation No: 3.8.2.1 Compressive strength test

S.No	Type of Concrete	Compressive strength(Mpa)		
		7 Days	14 Days	28 Days
1	Traditional Concrete	31.36	41.12	49.2
2	Ultrafine Slag Concrete -1 (10 %)	33.47	43.77	51.5
3	Ultrafine Slag Concrete -2 (15 %)	36.14	47.26	54.12
4	Ultrafine Slag Concrete -3 (20 %)	34.9	45.32	52.3

3.8.2.2 Split Tensile Strength Test

Tabulation No:3.8.2.2 Split Tensile Strength Test Results

S.No	Type of Concrete	Split Tensile Strength Test(Mpa)		
		7 Days	14 Days	28 Days
1	Traditional Concrete	3.22	5.5	6.5
2	Ultrafine Slag Concrete -1 (10 %)	4.61	7.2	8.95
3	Ultrafine Slag Concrete -2 (15 %)	5.12	9.11	10.33
4	Ultrafine Slag Concrete -3 (20 %)	4.95	8.8	9.2

3.8.2.3 Flexural Strength Test

Tabulation No: 3.8.2.3 Flexural Strength Test

S.No	Type of Concrete	Flexural Strength Test(Mpa)		
		7 Days	14 Days	28 Days
1	Traditional Concrete	6.27	8.2	9.9
2	Ultrafine Slag Concrete -1 (10 %)	8.2	9.95	10.3
3	Ultrafine Slag Concrete -2 (15 %)	9.45	11.2	12.5
4	Ultrafine Slag Concrete -3 (20 %)	8.9	10.94	11.9

4.0 METHODOLOGY

This study focuses on the behavior and design of prestressed concrete systems. The methodology includes selection of materials, identification of prestressing components, execution procedures, and structural design of beams. All processes are carried out in accordance with relevant Indian Standard codes.

4.2.1 Prestressing System

The prestressing system consists of high-strength steel tendons, ducts, and anchorage devices. The tendons are used to apply compressive force to concrete, while ducts provide a path for tendon placement in post- tensioning. Anchorage systems are used to transfer and maintain the prestressing force within the concrete member.

4.3 Materials and Equipment

Prestressing steel of high tensile strength is used along with concrete of grade M40. The equipment employed includes hydraulic jacks, pumps, strand dispensers, and grouting machines. These tools ensure accurate application of prestressing force and proper execution of the process.

4.4 Tendon Systems

Two types of tendon systems are considered:
Bonded system, where tendons are grouted after stressing to develop bond with concrete.
Unbonded system, where tendons are greased and sheathed, allowing free movement without bonding.
The tendon profile is selected based on bending moment distribution.

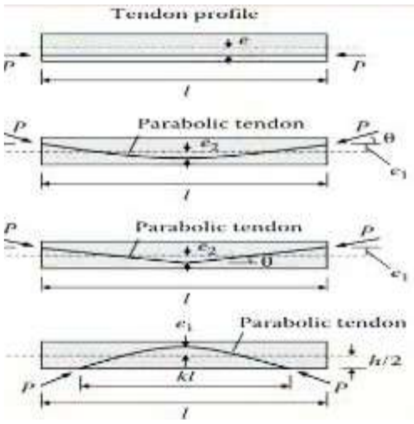


Diagram No: 4.4.2 Profile of Tendon

4.5 Construction Procedure

The prestressing process is carried out in the following steps:

- Preparation and proper storage of materials
- Placement of reinforcement and tendons
- Fixing of ducts and anchorages
- Concreting and curing
- Stressing of tendons using hydraulic jacks after required strength is achieved
- Cutting of excess tendons
- Grouting of ducts to ensure bonding and corrosion protection

4.7 Design Methodology

The design of beams is carried out using standard code provisions. RCC beams are designed using the Limit State Method as per IS 456, while PSC beams are designed as per IS 1343. Loads, bending moments, shear forces, and deflections are calculated to ensure structural safety and serviceability.

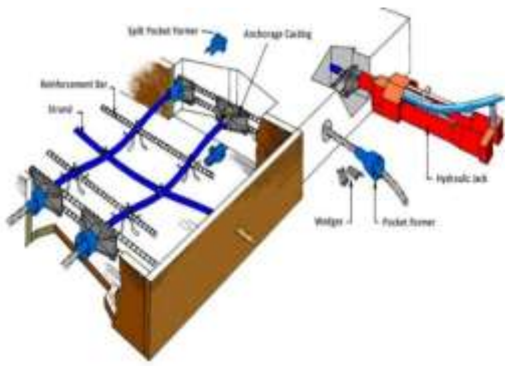
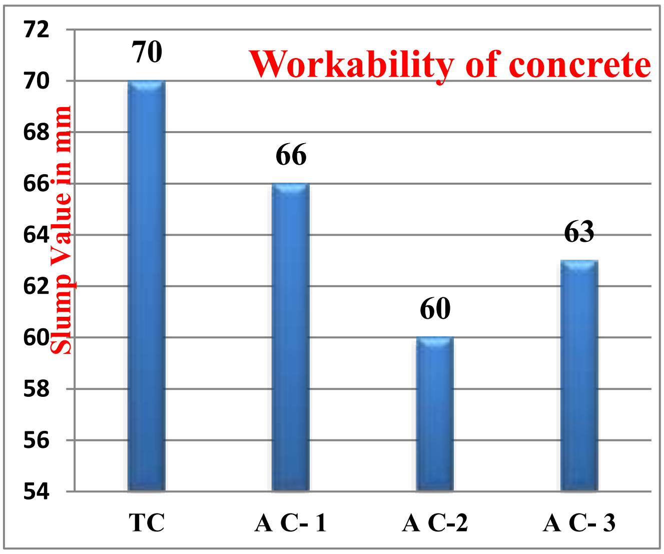


Diagram No: 4.4.4 Working Mechanism

5.0 RESULT ANALYSIS

5.2.1 Results Analysis on Fresh Concrete

5.2.1.1 Slump Cone test Result analysis



5.2.2 Results Analysis on Hardened Concrete

5.2.2.1 Compressive Strength Test

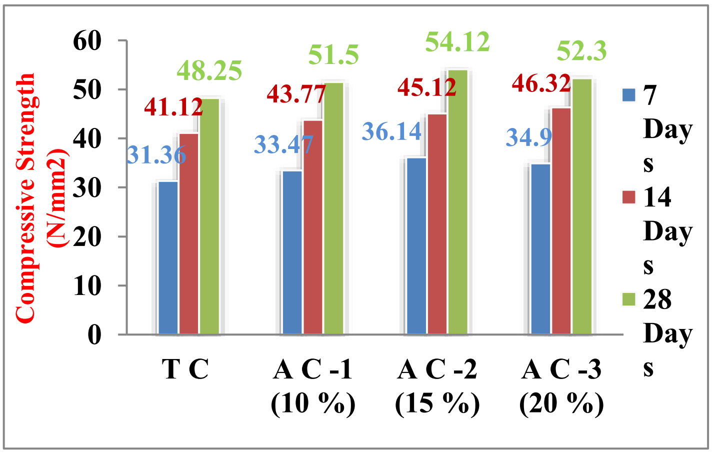


Diagram No: 5.2.2.1Results Analysis of Compressive Strength Test

5.2.2.2 Split Tensile Strength Test

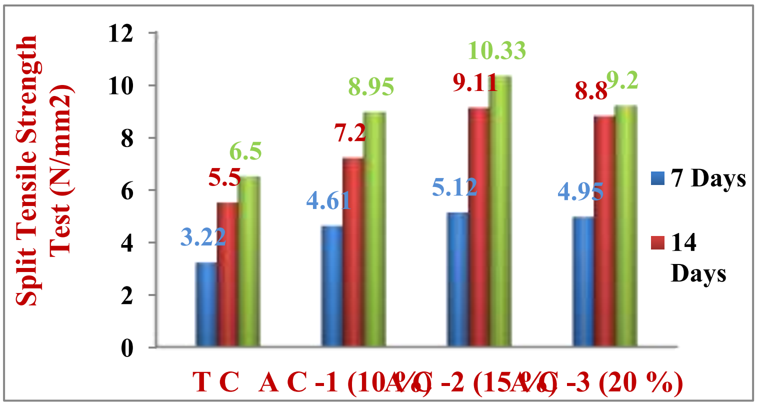


Diagram No: 5.2.2.2 Results Analysis of Split Tensile Strength Test

5.2.2.3 Flexural Strength Test

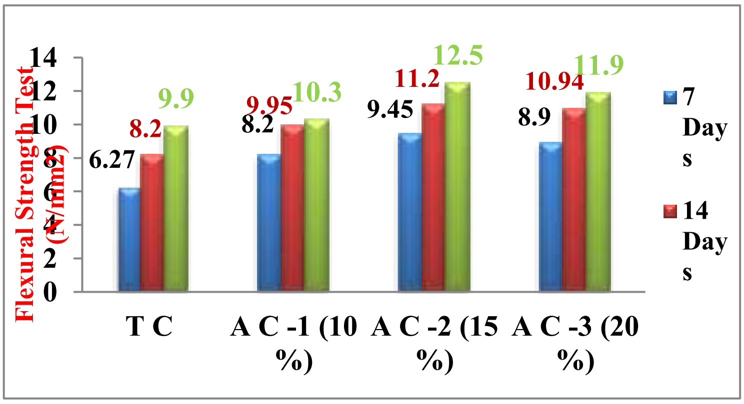


Diagram No: 5.2.2.3Results Analysis of Flexural Strength Test

5.3 Analysis of Beams

5.3.1 Quantities from Design

Tabulation No:5.3.1 Quantities from Design

S.No	Material	RCC	PSC
1	Concrete	30 m³	15 m³
2	Reinforcement Steel	1.95 Tons	0.20 Tons (mild steel)
3	Prestressing Steel	-	0.78 Tons
4	Total Steel	1.95 Tons	0.98 Tons

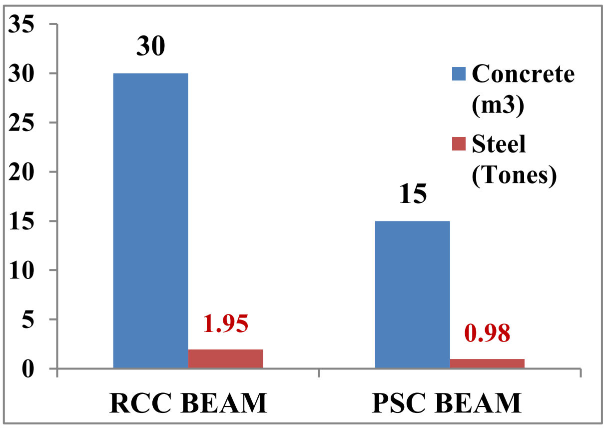
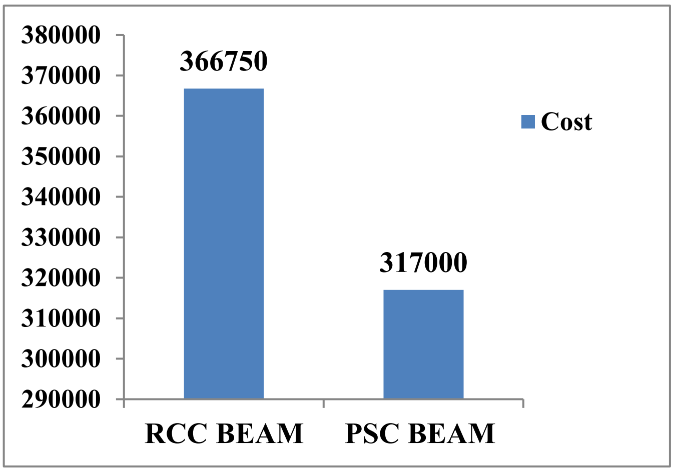


Fig No : 5.3.1Comparision of Quantities from Design

5.3.2 Comparison of cost (As per SSR-2026)

Tabulation No:5.3.2 Comparison of cost (As per SSR-2026)

S.No	Material	R C C BEAM			PSC BEAM		
		Qty	Rate	Amount	Qty	Rate	Amount
1	Concrete	30	8000	2,40,000	15	8000	1,20,000
2	Steel	2	65,000	1,26,750	0.2	65,000	13,000
3	PSC Steel	-	-	-	0.8	95,000	74,100
4	Anchorage + Duct + Stressing Charges						1,10,000
Toatl				3,66,750			3,17,000



S.NO	Item	RCC	PSC
01	Total Cost	₹3.67 L	₹3.17 L
02	Concrete Quantity	High	50% Less
03	Steel Quantity	High	Lower
04	Deflection	Higher	Much Lower
05	Cracking	Possible	Controlled
06	Long Span Suitability	Limited	Excellent

6.1 Conclusion

- In fresh concrete, The slump cone test the traditional concrete is obtained 70 mm slump value, and alcccofine are added in to the concrete with diffreent propotion. The optimum range is 15 % of Ultrafine Slag replacement by cement weight . it is recorded slump value is 60 mm. Beyond that rising the slump value.
- In Compressive strength of traditional concrete obtained 49.20 N/mm2. The optimum range strength is obtained at 15 % of Ultrafine Slag replacement by cement weight is obtained 54.12 N/mm2.Hence, the compressive strength of the cubes is increased by 10.33 % of traditional concrete strength**.**
- Similarly The split Tensile strength and Flexural strength of the specimen are also increased by 18 % and 21.22 % as compare with traditional concrete
- Variation in Quanties,The rate also changed Comparison with RCC Beam with PSC Beam. PSC beam cost is less .Comparison with RCC Beam with PSC Beam, Observed that PSC saves nearly 50% concrete, Steel quantity also reduced significantly.

6.2 Future Scope

- Higher Strength Grades and Performance Optimization Future work can extend the investigation to higher grades such as M50, M60, and ultra-high-performance concrete.
- Structural Behaviour under Advanced Loading:Future research may include: Cyclic loading and fatigue behavior, Seismic performance studies, Impact and blast resistance, Shear and torsional performance
- Use of Hybrid and Sustainable Materials: Future scope includes combining Ultrafine Slag with:Silica fume, Fly ash, GGBS, Fiber reinforcement (steel, basalt, polypropylene)
- Numerical Modelling and Software Simulation: Finite Element Modelling (FEM) using advanced software (ANSYS, ABAQUS, ETABS) can be carried out to simulate beam behavior and validate experimental results. Predictive models can be developed for strength and durability performance.

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