International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 • Website: www.ijfmr.com • Email: editor@ijfmr.com

Performance Evaluation of Self-Curing Concrete Incorporating Polyethylene Glycol (PEG-400) and GGBS for M30, M50, and M70 Grades

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Abstract

Curing is an essential process in concrete construction that ensures adequate moisture retention during the early stages of hydration. However, practical challenges often hinder effective curing, especially in remote or water-scarce environments. As a sustainable alternative, self-curing techniques have gained attention. This study investigates the influence of Polyethylene Glycol (PEG-400) as a self-curing agent and Ground Granulated Blast Furnace Slag (GGBS) as a partial cement replacement on the mechanical performance of concrete. Concrete mixes of M30, M50, and M70 grades were developed with PEG-400 dosages ranging from 0% to 2% by weight of cement and GGBS replacing cement from 0% to 40%. The mechanical properties — compressive strength, split tensile strength, and flexural strength — were evaluated at 28 days. Results revealed that the optimum PEG-400 dosage (1.0–1.5%) and GGBS content (10–20%) significantly improved the strength properties, with gains of approximately 10%–15% over conventional concrete. This combination also improved hydration and internal moisture retention.

Keywords: Self-curing concrete, PEG-400, GGBS, Internal curing, High-strength concrete, Compressive strength, Split tensile strength, Flexural strength.

1. Introduction

Concrete is the cornerstone of modern infrastructure due to its excellent mechanical and durability properties. However, inadequate curing can result in incomplete hydration, increased porosity, and reduced long-term performance. Conventional external curing is often difficult in real-world conditions, necessitating internal curing approaches.

Self-curing (internal curing) employs hydrophilic materials like PEG-400 to retain water within the concrete matrix. Concurrently, GGBS, an industrial by-product, enhances durability and sustainability while participating in secondary hydration reactions, forming additional calcium-silicate-hydrate (C-S-H) gel. This study focuses on the mechanical characterization of self-curing concrete mixes for M30, M50, and M70 grades, incorporating PEG-400 and GGBS

2. Research Significance

- To evaluate the effect of PEG-400 (0%–2%) and GGBS (0%–40%) on the strength performance of M30, M50, and M70 grade concretes.
- To identify the optimum PEG-400 and GGBS combination that maximizes strength.
- To develop a sustainable self-curing concrete mix suitable for field conditions where conventional curing is impractical.
- To perform SEM analysis for microstructural evaluation and support mechanical test results.

3. Literature Review

Jagannadha Kumar et al. (2018) extended their study to high-strength concretes and observed that PEG-400 at 0.5% dosage was optimal for M60 grade concrete, resulting in improved hydration and strength gain even without external water curing. The self-curing effect significantly reduced early-age shrinkage and enhanced the microstructure.

Mousa et al. (2014) evaluated the internal curing efficiency of PEG-400 and pre-soaked LECA in high-performance concrete. Their results showed that PEG-400 led to better early-age compressive strength, reduced capillary porosity, and improved water retention — features essential for grades above M50.

Vadivel et al. (2019) investigated M60 concrete with PEG-400 dosages ranging from 1% to 3% in combination with silica fume (15%–20%). The study concluded that 1% PEG with 20% silica fume was optimal, achieving enhanced strength and durability, suitable for high-performance applications.

Anil Podeti (2020) studied advanced concretes incorporating PEG-400 and recycled superabsorbent polymers. For high-grade mixes like M60+, the incorporation of 1% PEG-400 was found to significantly improve workability and self-curing capacity, making the concrete more sustainable and durable under harsh curing conditions.

4. Experimental Program

4.1 Materials Used:

- **Cement**: OPC 53 grade (IS 12269:1987)
- **Fine Aggregate**: Zone II river sand (IS 383:1970)
- **Coarse Aggregate**: Crushed granite, max. size 20 mm
- **Water**: Potable water
- **GGBS**: Fineness 400–600 m²/kg from JSW Steel Ltd.
- **Self-Curing Agent**: PEG-400 (molecular weight: 400)
- **Superplasticizer**: Conplast SP430 (used in M70)

4.2 Mix Proportions:

Grade	Cement (kg/m³)	Fine Aggregate (kg/m³)	Coarse Aggregate (kg/m³)	Water (kg/m³)	GGBS (%)	PEG-400 (%)	Superplasticizer (%)
M30	360	735	1205	162	0–40	0–2	–
M50	430	670	1210	150	0–40	0–2	–
M70	540	600	1190	144	0–40	0–2	1.0

4.3 Mix Designation Examples:

- **C00G00P** → 100% cement, 0% GGBS, 0% PEG
- **C20G1.5P** → 80% cement, 20% GGBS, 1.5% PEG-400

4.4Procedure:

Concrete was mixed in a standard mixer. PEG-400 was mixed with half the mixing water before addition. Specimens were cast in cubes (150×150×150 mm), cylinders (150×300 mm), and prisms (100×100×500 mm). Conventional specimens were water-cured; self-curing mixes were left in ambient air. Tests were performed at 7,14,28 days.

5.0 Results and Discussion:

Compressive Strength M30

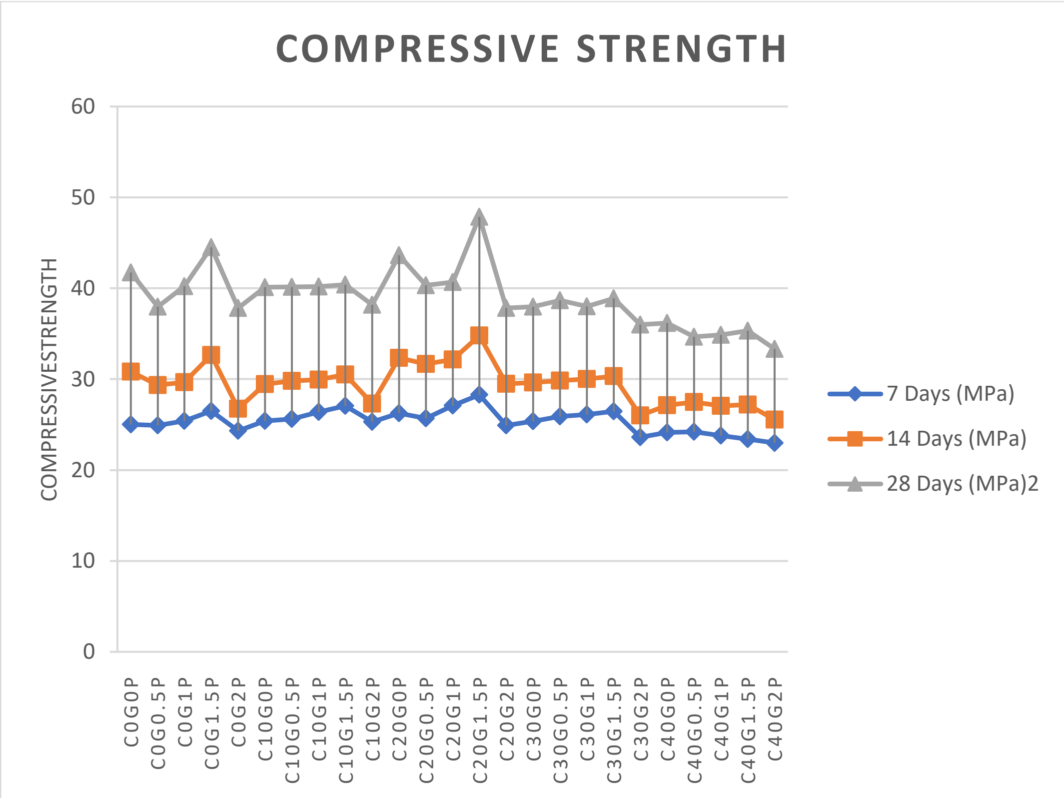

Figure : Compressive Strength of M30 Grade of Concrete

The compressive strength of M30 grade self-curing concrete improves with curing age, and optimum results are observed with moderate additions of curing compound and glass fibers. Mix C20G1.5P recorded the highest strength of 47.87 MPa at 28 days, indicating the best performance among all combinations. Strength development from 7 to 28 days is consistent in most mixes, especially those with balanced admixture content. However, mixes with excessive fiber content (G2), particularly in the C30 and C40 series, show a noticeable drop in strength, likely due to reduced compaction and poor fiber dispersion. The control mix C0G0P, although performing decently, falls short compared to optimized mixes, confirming the benefit of admixture incorporation within appropriate limits.

Flexural Strength M30

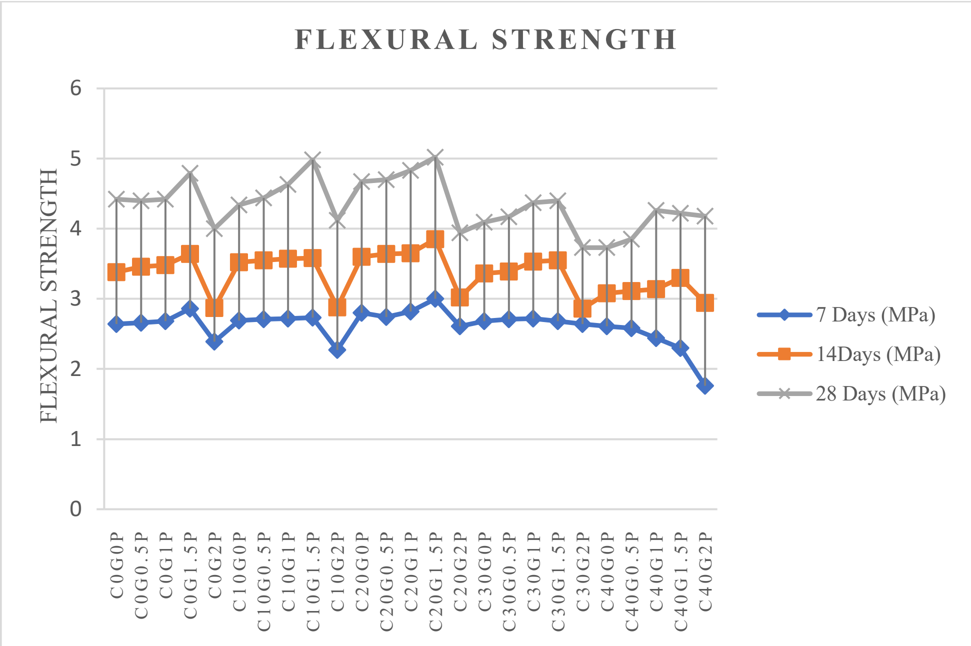

Figure : Flexural Strength of M30 Grade of concrete

Flexural strength of M30 self-curing concrete increases with curing age and shows optimal performance with up to 20% GGBS and 1.5% PEG 400. The maximum strength of 5.02 MPa at 28 days is observed in mix C20G1.5P. Beyond this dosage, particularly with G2 mixes, a decline in strength is evident. The increase in strength over time indicates effective hydration supported by self-curing agents, while the decrease in higher dosage mixes suggests issues like excess water retention or poor fiber integrating's and 1.5% PEG400, which is greater than 13.41% compared to standard concrete.

Split Tensile Strength M30

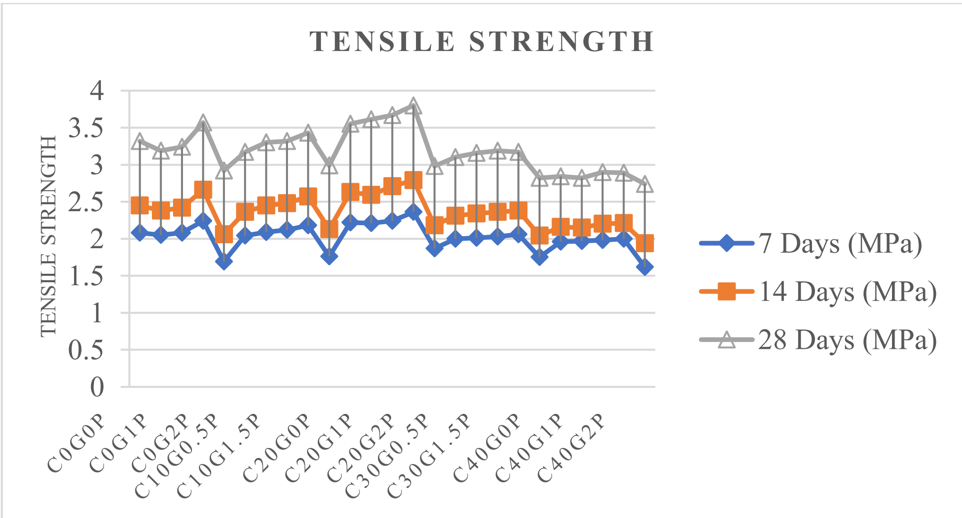

Figure : Split Tensile Strength of M30 Grade of concrete

Split tensile strength also improves with age, peaking at 3.8 MPa in mix C20G1.5P at 28 days. Moderate additions of PEG 400 and GGBS enhance strength, especially up to 1.5% PEG and 20% GGBS. However, mixes with 2% PEG (G2) show reduced tensile strength, indicating that excessive dosage negatively affects bond and matrix quality. The control mix C0G0P performs lower in comparison, confirming the effectiveness of optimized self-curing additives..

Compressive Strength M50

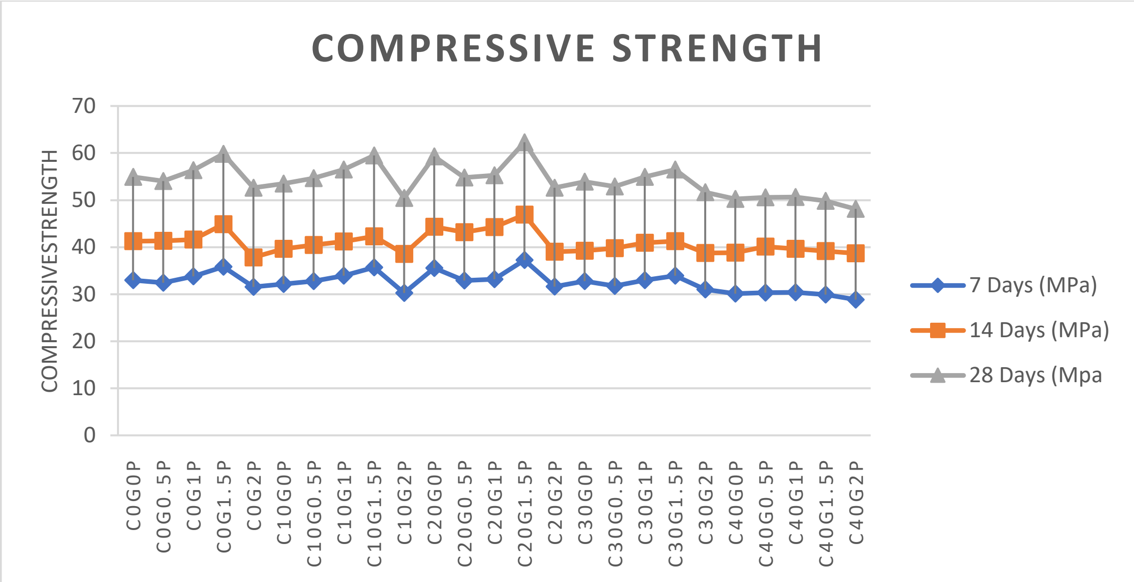

Figure : Compressive Strength of M50 Grade of Concrete

Compressive strength of M50 self-curing concrete shows a steady increase with curing age and reaches its peak with mix C20G1.5P, achieving 62.29 MPa at 28 days. The strength improves with increasing GGBS and PEG400 up to the optimal combination of 20% GGBS and 1.5% PEG400. Beyond this dosage, particularly in G2 mixes, a noticeable reduction in strength is observed, likely due to reduced hydration efficiency and mix stability. The control mix C0G0P, while achieving decent strength, is outperformed by mixes with optimized self-curing additives.

Flexural Strength M50

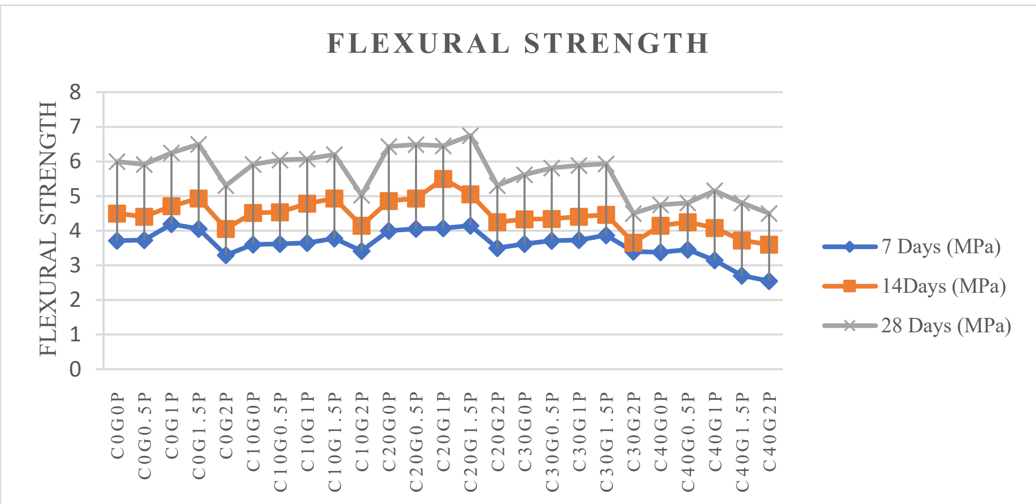

Figure : Flexural Strength of M50 Grade of concrete

Flexural strength trends indicate a similar pattern, with strength increasing over time and reaching a maximum of 6.75 MPa in mix C20G1.5P at 28 days. The addition of GGBS and PEG400 enhances flexural capacity up to a certain limit, after which excessive dosage leads to a reduction in performance. This is evident in C30G2P and C40G mixes, where strength values drop significantly. The results confirm that moderate dosing ensures effective bonding and stress distribution under bending loads.

Split Tensile Strength M50

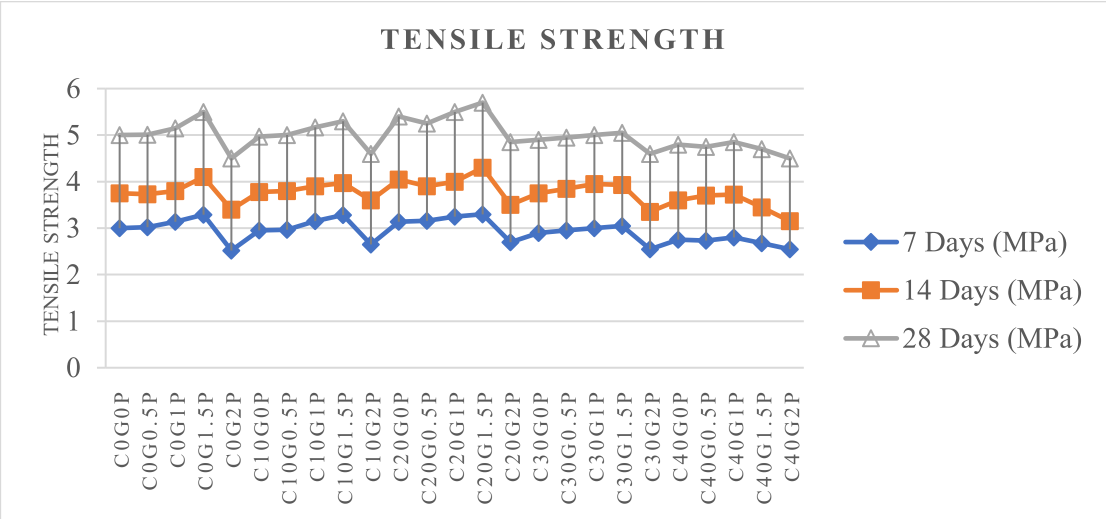

Figure : Split Tensile Strength of M50 Grade of concrete

Split tensile strength also improves across all curing ages, with the highest value of 5.7 MPa observed in mix C20G1.5P. Mixes with optimal admixture content show better crack resistance and matrix bonding. However, excessive PEG400 (as in G2 mixes) results in reduced tensile strength, likely due to fiber-matrix incompatibility or excess voids. Compared to the control mix, optimized formulations offer improved tensile performance, confirming the beneficial effects of carefully balanced self-curing agents and mineral admixtures.

Compressive Strength M70

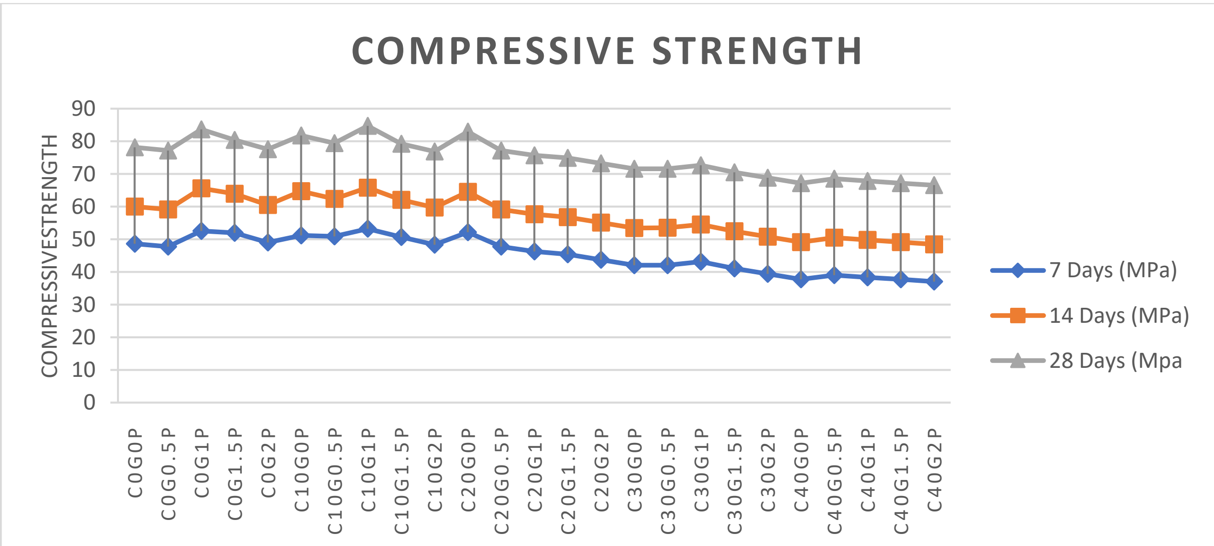

Figure Compressive Strength of M70 Grade of Concrete

For M70 grade self-curing concrete, compressive strength improved consistently with curing time. The maximum strength was recorded at a mix containing 10% GGBS and 1.0% PEG400, showing a significant increase compared to conventional concrete. However, increasing GGBS and PEG400 beyond this threshold led to a decrease in compressive strength, likely because of the adverse effects of excessive supplementary materials on the cement matrix.

Flexural Strength M70

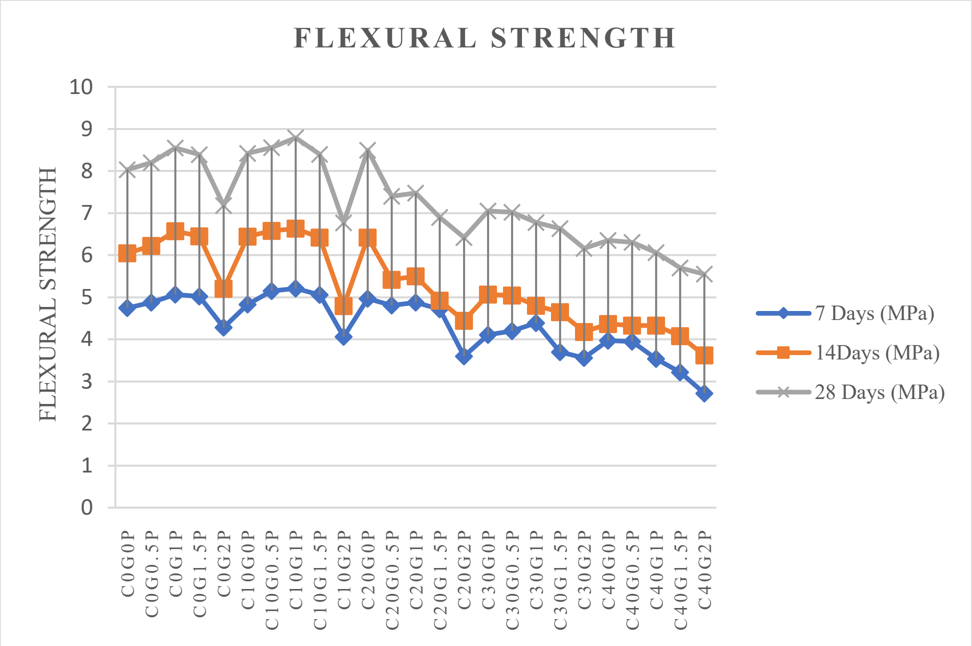

Figure : Flexural Strength of M70 Grade of concrete

The flexural strength of M70 grade concrete increased steadily with the addition of GGBS and PEG400 up to the optimal dosage of 10% GGBS and 1.0% PEG400. This optimal mix exhibited a notable improvement compared to the control mix. Beyond this point, the flexural strength declined, reflecting the negative impact of excess GGBS and PEG400 on the concrete's resistance to bending forces..

Split Tensile Strength M70

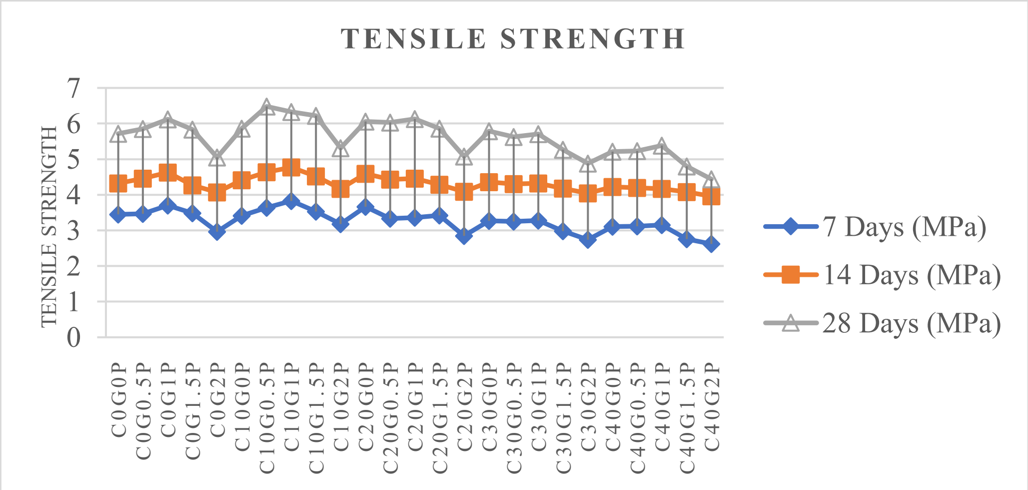

Figure : Split Tensile Strength of M70 Grade of concrete

Split tensile strength of M70 grade concrete also followed this pattern, with the highest values at moderate replacement levels. The strength decreased once the replacement level exceeded the optimum, suggesting that too much GGBS and PEG400 impairs the tensile strength due to compromised bonding and structural integrity.

6.Conclusion:

M30 Grade Concrete:

- The compressive, flexural, and split tensile strengths increased with PEG-400 and GGBS addition up to 20% GGBS + 1.5% PEG.
- Mix C20G1.5P achieved the highest compressive strength of 47.87 MPa, about 14.7% higher than the control.
- Flexural and tensile strengths also peaked at this mix, confirming optimal internal curing and matrix densification.
- Strength declined beyond 1.5% PEG due to poor dispersion and reduced workability.

M50 Grade Concrete:

- Strength development followed a similar trend, with maximum performance at 20% GGBS + 1.5% PEG (Mix C20G1.5P).
- Compressive strength reached 62.29 MPa, 13.4% higher than the control.
- Flexural and tensile strengths were also enhanced, showing a balanced improvement in durability and mechanical behavior.
- Excessive PEG (2%) negatively impacted workability and bonding, reducing strength.

M70 Grade Concrete:

- Optimum results were observed at a lower dosage of PEG and GGBS: 10% GGBS + 1.0% PEG (Mix C10G1P).
- Compressive strength peaked at 84.73 MPa, an 8.4% improvement over the control.
- Higher-grade concrete showed greater sensitivity to overdosage, with strength significantly declining beyond the optimum.
- Flexural and tensile strength improvements confirmed enhanced hydration, but excess GGBS/PEG led to matrix dilution.

Overall Conclusion:

- PEG-400 is an effective internal curing agent for M30 to M70 grades when used in controlled dosages.
- Optimal PEG dosage:
  - M30, M50: 1.5%
  - M70: 1.0%
- Optimal GGBS dosage:
  - M30, M50: 20%
  - M70: 10%
- Overdosage adversely affects performance due to bleeding, reduced hydration efficiency, or microcracking.
- Mix C20G1.5P (for M30 and M50) and C10G1P (for M70) are recommended for best strength and durability in self-curing applications.

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