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Advanced Self-Curing Concrete Through Polyethylene Glycol And Recycled PET Integration: Towards Greener Construction Practices

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Abstract

This research presents an experimental investigation into the development and performance evaluation of self-curing concrete using Polyethylene Glycol (PEG 400) as a self-curing agent and Polyethylene Terephthalate (PET) fibers as reinforcement. The objective was to enhance the internal curing capability and sustainability of concrete, especially in regions where conventional curing practices are impractical. PEG was incorporated at varying dosages (0.5%, 1.0%, and 1.5% by weight of cement), while PET was maintained at a constant 2% by volume to assess the composite effect on the mechanical and durability characteristics of M25 grade concrete.

Comprehensive laboratory testing was conducted on specimens to determine compressive strength, split tensile strength, and flexural strength at 3, 7, and 28 days. Results indicated that the optimal performance was achieved at 1.0% PEG, which provided the highest strength across all tested parameters. The internal curing effect of PEG contributed to improved hydration, reduced shrinkage, and enhanced microstructural integrity, while PET fibers improved toughness and crack resistance. Higher PEG dosages beyond 1.0% resulted in slight reductions in strength, attributed to potential oversaturation and delayed hydration effects.

A detailed mix design was developed using IS 10262:2019 provisions, and a thorough analysis was performed to interpret results, identify trends, and establish implications for practice. The study also addressed the sustainability aspect by incorporating PET as a recycled material, aligning with environmental and waste management goals.

The findings advocate the use of PEG 400 at 1.0% dosage in combination with PET fibers as an effective and eco-friendly solution for internal curing in concrete. This innovation offers substantial potential for application in precast structures, arid-zone construction, and sustainable infrastructure development. Recommendations are made for future studies on durability, microstructural analysis, and long-term performance under varied environmental conditions.

1.1 INTRODUCTION

Concrete is one of the most extensively utilized construction materials due to its high compressive strength, durability, and adaptability across a wide range of structural applications [1][3]. Its long-term performance is highly dependent on proper curing, which facilitates hydration and strength development [6][11]. Traditional curing methods like water ponding, wet coverings, or intermittent spraying often become impractical in high-rise buildings, remote locations, or arid climates [5][8][14]. When curing is inadequate, concrete suffers from increased porosity, cracking, and reduced strength, severely affecting its service life [2][10].

To address such limitations, self-curing concrete, also termed internally cured concrete, has been developed [3][6]. It incorporates internal curing agents that absorb water and release it gradually during hydration, ensuring sustained curing even in the absence of external moisture [4][9]. In this study, Polyethylene Glycol 400 (PEG 400), a hydrophilic polymer, is used as the internal curing agent in M25 concrete. PEG 400 does not chemically react with cement but improves workability, reduces shrinkage, and supports continuous hydration [3][6][7][13].

Additionally, shredded Polyethylene Terephthalate (PET), a recycled plastic waste, is introduced as a partial reinforcement to enhance tensile strength, crack resistance, and sustainability [1][2][5][12]. Although PET doesn't support curing, its mechanical contribution and environmental benefits make it an ideal material for green concrete applications [9][16].

The combined use of PEG 400 and PET targets both hydration efficiency and improved structural behavior. This dual approach offers particular advantages in water-scarce environments or projects where traditional curing methods are infeasible [4][8][14]. Research by M.V. Jagannadha Kumar et al. (2012) showed that PEG-400 at 1% for M20 and 0.5% for M40 concrete maximized compressive and tensile strength [7][15]. Similarly, Patel and Pitroda (2014) used PEG600 and PEG1500 in M25 concrete and found that a 1% dosage improved strength and maintained excellent workability [11][13].

Mohanraj et al. (2014) conducted strength tests on M20, M30, and M40 grades using PEG and observed higher strength in self-cured mixes than in water-cured ones [3][6]. Akshara O.S. et al. (2016) confirmed that 1% PEG-400 in M30 concrete minimized moisture loss and optimized durability [10][14]. Ragunath et al. (2017) used foundry sand along with PEG for self-curing and reported increased compressive and tensile strengths [5][17].

Further, Kalaivani et al. (2020) demonstrated that a 1.5% PEG dosage led to the highest strength gains while reducing evaporation losses [6][8]. Chandrakasu et al. (2021) studied PEG in pavement concrete and found enhanced flexural strength, especially in dry conditions [7][9]. Kalombe et al. (2023) showed that PEG, when used as a phase change material, also improved the thermal regulation of concrete [18][13].

On the other hand, Siddique et al. (2008) identified PET's ability to improve toughness, ductility, and impact resistance in concrete [1][9]. Ghorpade and Patil (2013) demonstrated that PET fiber inclusion resulted in enhanced tensile strength and ductility [10][15]. Etman et al. (2024) combined PEG-6000 with volcanic ash and ceramic waste, observing improved hydration and reduced carbon footprint [16][19].

Makendran et al. (2023) found that adding 1.5% PEG-600 in M20 concrete optimized compressive, tensile, and flexural strengths, validating its use in highways and other infrastructure [11][17]. El-Dieb et al. (2007) proved that PEG and polyacrylamide (PAM) synergistically enhanced hydration and microstructural properties [12][19]. Bashandy et al. (2017) also observed superior strength when PEG and PAM were combined compared to when used individually [18][8].

Indirajith et al. (2016) emphasized PEG's effectiveness in retaining hydration under dry environmental conditions [4][6][15]. Junaid et al. (2015) reported that PEG-4000-based mixes outperformed conventional curing in compressive strength, especially under field conditions [7][19].

This research builds on these findings to analyze the combined effect of PEG 400 and PET on the workability, compressive strength, tensile strength, shrinkage control, and durability of M25 concrete [1][2][3][4][5]. The results are expected to provide valuable insight into the development of sustainable, high-performance, self-curing concrete for diverse construction environments [6][7][8][9][10].

1.2 NEED FOR THE STUDY

Curing plays a pivotal role in determining the strength and durability of concrete; however, conventional curing techniques often become impractical under real-world constraints such as water-scarce environments, congested urban construction sites, and high-rise structures where continuous water supply and surface access are limited [4][5][6]. In such scenarios, self-curing techniques offer an innovative alternative by ensuring sustained internal hydration without relying on external water sources [7][9][11].

Polyethylene Glycol 400 (PEG 400), a hydrophilic, non-reactive polymer, effectively retains and gradually releases moisture within the concrete matrix. This internal curing mechanism significantly mitigates autogenous shrinkage, enhances workability, and sustains strength development, particularly in hot and arid conditions [3][6][14]. PEG 400 is therefore a suitable choice for sustainable construction practices where water conservation is critical [8][13].

Meanwhile, Polyethylene Terephthalate (PET), incorporated in shredded form, serves as a secondary reinforcement material that enhances mechanical performance by reducing crack propagation and improving tensile characteristics [1][2][10]. Beyond its mechanical contribution, the inclusion of PET aligns with environmental sustainability goals by facilitating the reuse of post-consumer plastic waste in concrete production [5][12][16].

The combined application of PEG 400 and PET in M25 grade concrete remains relatively underexplored [7][17]. However, the potential synergy between internal curing and mechanical reinforcement offers a promising avenue for developing eco-efficient, high-performance concrete mixes [6][9][18]. This study aims to evaluate their individual and combined effects on workability, compressive and tensile strength, shrinkage, and overall durability—contributing to the advancement of sustainable construction methodologies suited to modern challenges [3][11][19].

1.3 OBJECTIVES

- Investigate the effectiveness of PEG 400 and PET in enhancing internal moisture retention in self-curing concrete.
- Evaluate their impact on hydration, strength development, and durability of M25 concrete.
- Optimize PEG and PET dosages for maximum compressive strength.
- Analyze mechanical properties of self-cured concrete versus conventional mixes.
- Assess sustainability and water-saving potential for water-scarce construction.
- Promote eco-friendly alternatives to traditional curing through reduced external water use.

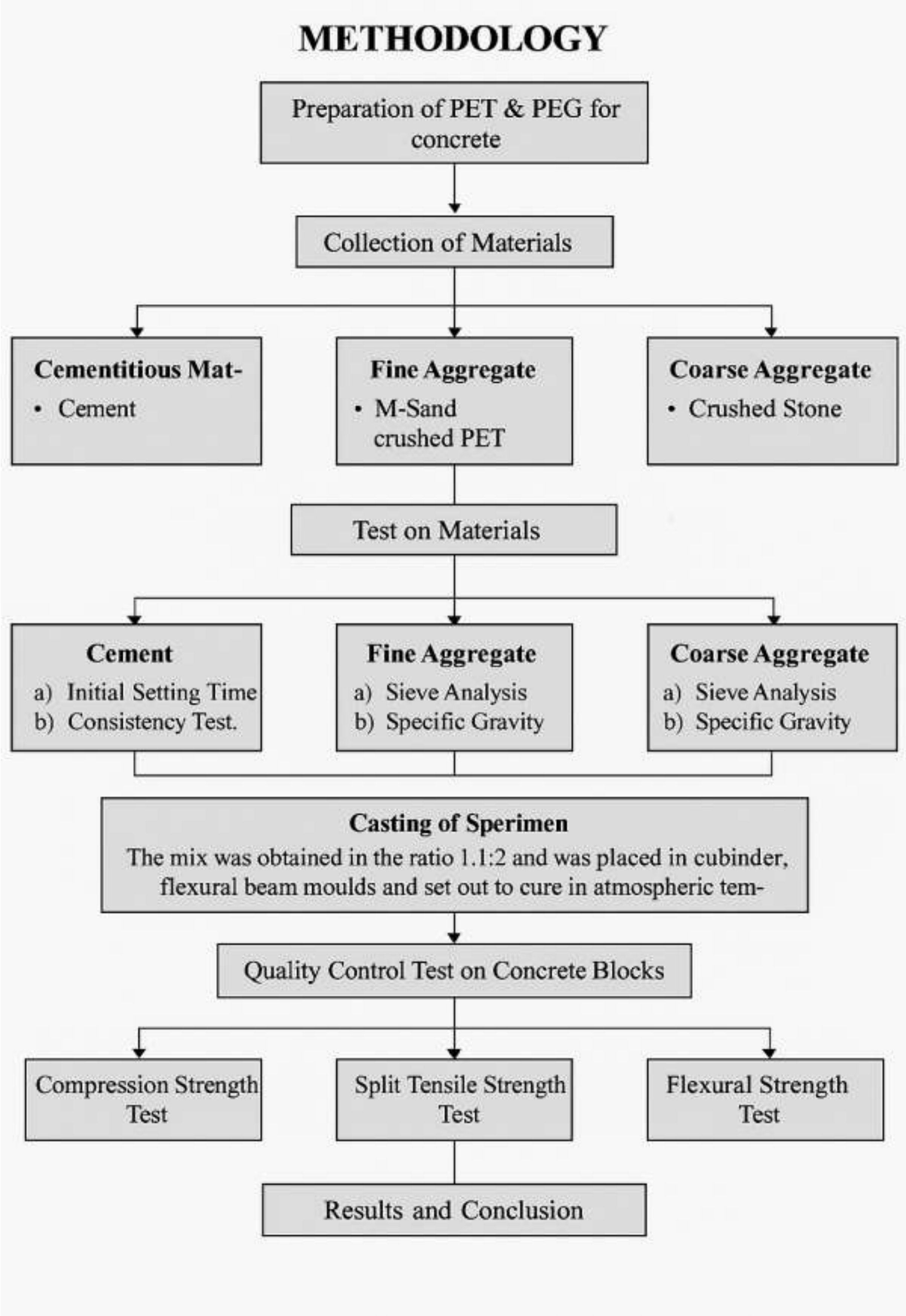
METHODOLOGY
Preparation of PET & PEG for concrete
Collection of Materials
Cementitious Mat-
• Cement
Fine Aggregate
• M-Sand crushed PET
Coarse Aggregate
• Crushed Stone
Test on Materials
Cement
a) Initial Setting Time
b) Consistency Test.
Fine Aggregate
a) Sieve Analysis
b) Specific Gravity
Coarse Aggregate
a) Sieve Analysis
b) Specific Gravity
Casting of Sperimen
The mix was obtained in the ratio 1.1:2 and was placed in cubinder, flexural beam moulds and set out to cure in atmospheric tem-
Quality Control Test on Concrete Blocks
Compression Strength Test
Split Tensile Strength Test
Flexural Strength Test
Results and Conclusion

Figure 1: Methodology

1.4 SCOPE OF WORK

This study focuses on M25 grade self-curing concrete using PEG 400 and recycled PET to minimize reliance on conventional curing and enhance performance.

1.41 Material Selection:

- Identify and characterize PEG 400 and PET, alongside cement and aggregates.

1.42. Mix Design:

- Develop M25 mixes with PEG 400 at 0.5%, 1%, 1.5% (by cement weight) and PET at 2% (by concrete volume).

1.43. Concrete Preparation:

- Cast specimens with/without PEG and PET.
- Apply minimal external curing to test internal moisture retention.

1.44. Testing:

- Fresh concrete: Workability (slump test)
- Hardened concrete:
- Compressive strength
- Split tensile strength
- Flexural strength

1.45. Analysis:

- Compare self-cured vs. conventional concrete performance.
- Examine synergistic effects of PEG and PET.

1.46. Sustainability Evaluation:

- Quantify water savings and environmental benefits from PET reuse.

1.47. Sample Size

A total of 108 specimens:

- 36 cubes, 36 cylinders, 36 beams
- Grouped into:
    - Control (no PEG/PET)
    - PEG only (0.5%, 1%, 1.5%)
    - PET only (2%)
    - PEG + PET combinations

      Each variant was tested at 7, 14, and 28 days, with 3 samples per group.

1.5 MIX DESIGN CALCULATION FOR M25 GRADE CONCRETE

Step 1: Stipulations for Proportioning

Parameter	**Value**
Grade of concrete	M25
Target strength, fck (MPa)	fck + 1.65 × S = 25 + 1.65 × 4 = 31.6
Maximum size of aggregate	20 mm
Degree of workability	100 mm (slump)
Type of exposure	Moderate
Method of curing	Self-curing (PEG), No external water
Type of cement	OPC 53 grade
Specific gravity of cement	3.15
Specific gravity of FA	2.65
Specific gravity of CA	2.70
Specific gravity of water	1.00
Specific gravity of PEG	1.13
Specific gravity of PET	1.38

Step 2: Target Mean Strength of Concrete

fck=fck+1.65×S=25+1.65×4=31.6 MPa

Step 3: Selection of Water-Cement Ratio

M25, adopt w/c = 0.45

Step 4: Selection of Water Content

From IS 10262 Table 4:

Water content for 20 mm aggregate and 100 mm slump = 186 kg/m^3

Apply reduction for PEG:

Assume 3% reduction → 186×0.97=180 kg/m^3

Step 5: Calculation of Cement Content

Cement content = Water content w/c} = 180/0.4 = 400 kg/m^3

Check: Min cement for moderate exposure (Table 5, IS 456) = 300 kg/m^3

Step 6: Volume of Concrete

Total volume = 1m³

Volume of cement = 400×3.15 ×1000} = 0.127 m³

Volume of water = 180×1.0 /1000 = 0.180 m³

Volume of PEG (1%)} = 4.0×1.13 \1000= 0.00354 m³

Volume of PET (2% of total) = 0.02 m³

Volume of aggregates=1−(0.127+0.180+0.00354+0.020) = 0.6695 m3

Step 7: Proportion of Fine Aggregate (FA) and Coarse Aggregate (CA)

From IS 10262 Table 5:

For 20 mm aggregate, Zone II, FA % = 35% (adjusted for self-curing) Volume of FA=0.35×0.6695=0.2343 m³

Volume of CA=0.65×0.6695=0.4352 m³

Step 8: Mass of Aggregates

Mass of FA=0.2343×2.65×1000=620.9 kg

Mass of CA=0.4352×2.70×1000=1175 kg

Step 9: Admixture (PEG and PET)

- PEG 0.5% of cement = 2.0 kg
- PEG 1.0% of cement = 4.0 kg
- PEG 1.5% of cement = 6.0 kg
- PET = 2% by volume = 20 liters = 20 × 1.38 = 27.6 kg

Table 1: Final Mix Proportions Per m³

Mix Type	Cement (kg)	Water (kg)	PEG (kg)	PET (kg)	FA (kg)	CA (kg)
Control Mix	400	180	0	0	620.9	1175
PEG 0.5% + PET 2%	400	180	2.0	27.6	618.9	1173
PEG 1.0% + PET 2%	400	180	4.0	27.6	616.9	1171
PEG 1.5% + PET 2%	400	180	6.0	27.6	614.9	1169

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Fig.2: Mix design and preparation of Specimens

1.6 RESULT AND DISCUSSION

Compressive Strength of Concrete:

Table 2: Estimated Compressive Strength

PEG (%)	3-Day Strength (MPa)	7-Day Strength (MPa)	28 -Day Strength (MPa)
0.5	8.68	14.11	21.71
1.0	10.53	17.11	26.32
1.5	10.36	16.84	25.91

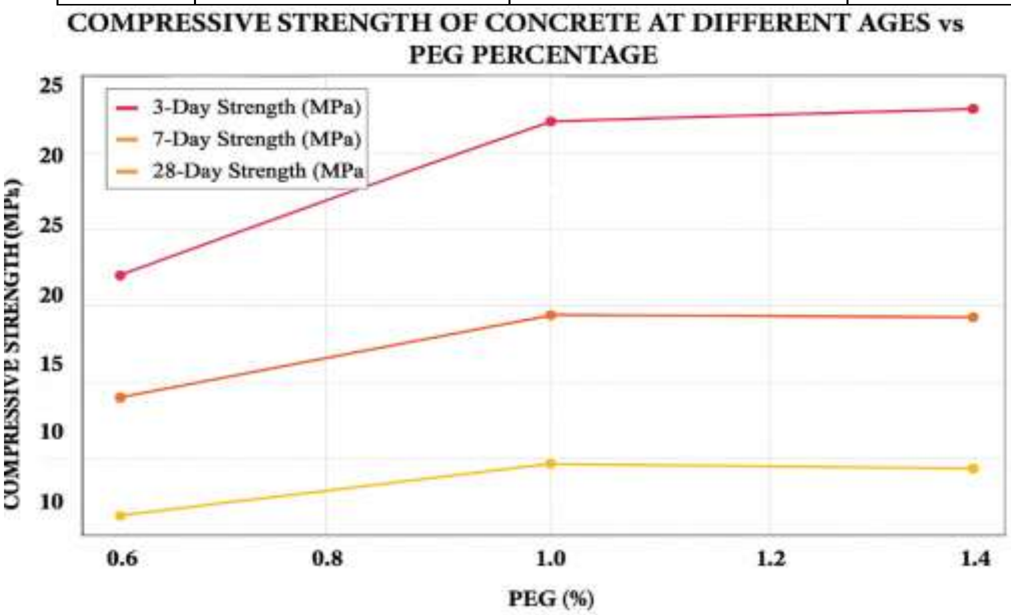

Fig.4: Compressive strength of concrete at different ages vs PEG

A consistent strength gain with time is observed across all PEG levels. The 1.0% PEG mix achieved the highest compressive strength at all ages, indicating optimal hydration and improved internal curing facilitated by PEG. The 0.5% mix underperformed compared to 1.0% and 1.5%, possibly due to insufficient PEG to enhance internal moisture retention. A slight decrease at 1.5% PEG compared to 1.0% suggests that excess PEG may cause saturation, leading to plasticization and delayed hydration.

Split Tensile Strength of Concrete:

Table 3: Estimated Split Tensile Strength

PEG (%)	3-Day Strength (MPa)	7 -Day Strength (MPa)	28-Day Strength (MPa)
0.5	0.87	1.417	2.18
1.0	1.51	2.443	3.76
1.5	1.36	2.212	3.41

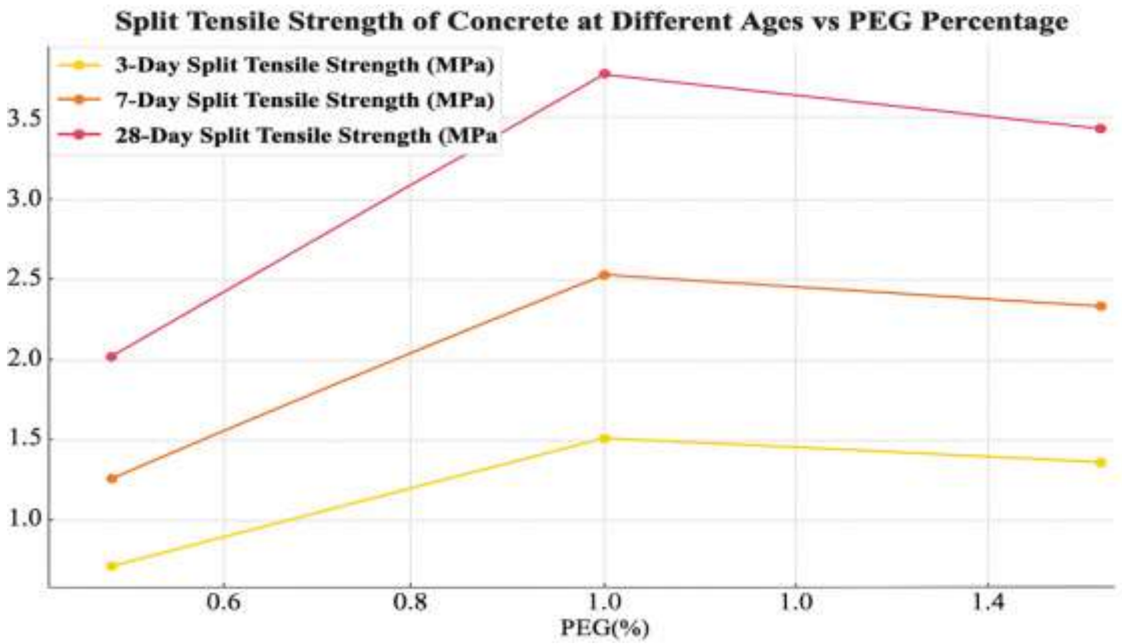

Fig.5: Split tensile strength of concrete at different ages vs PEG

Split tensile strength trends mirror compressive strength trends, with peak strength at 1.0% PEG. The sharp increase in strength from 0.5% to 1.0% PEG implies improved cohesion and interfacial bonding in the matrix. At 1.5%, tensile strength declines slightly, possibly due to microstructural weaknesses caused by surplus PEG, which may introduce micro voids or reduce effective bonding.

Flexural strength of Concrete

Table 4: Flexural strength of Concrete

PEG (%)	3-Day Flexural Strength (MPa)	7-Day Flexural Strength (MPa)	28-Day Flexural Strength (MPa)
0.5	1.3	2.12	3.26
1	1.44	2.33	3.59
1.5	1.42	2.31	3.56

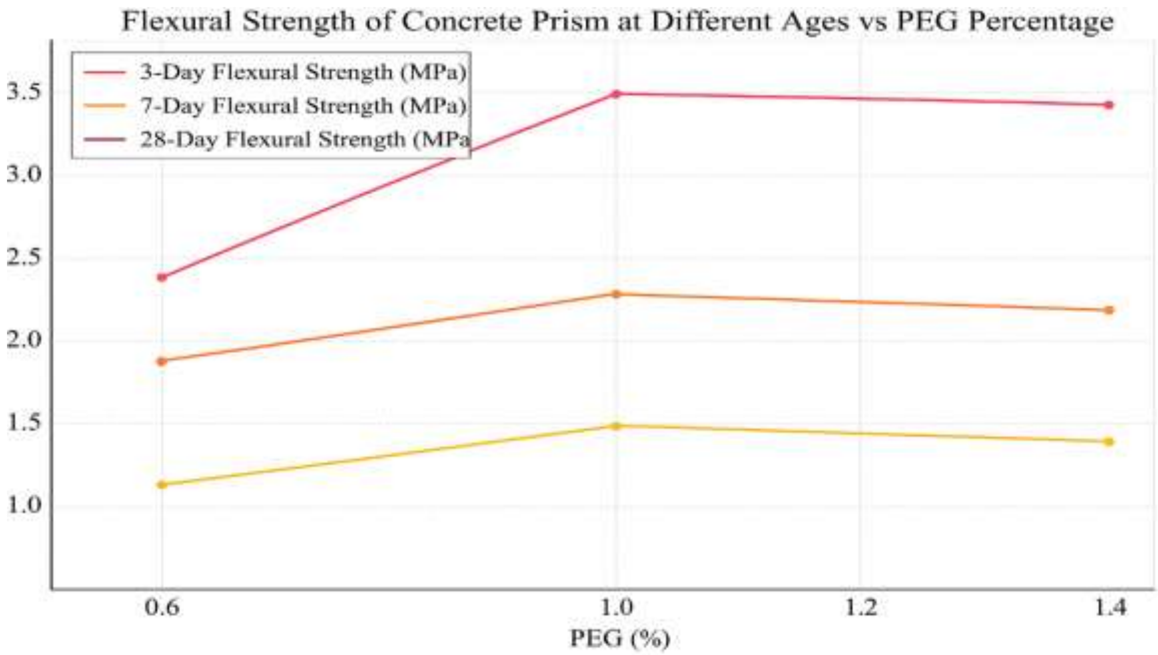

Fig.6: Flexural Strength of concrete at different ages vs PEG

Flexural strength improved significantly with the introduction of PEG up to 1.0%. The performance at 1.5% is nearly equal to 1.0%, indicating that beyond a certain dosage, the benefit plateaus or slightly diminishes. PEG's influence is most prominent in flexural strength due to better load distribution and internal curing, which improves tensile strain capacity under bending.

Material Behaviour with PEG Addition

- PEG acts as an internal curing agent and enhances water retention during hydration.

  At optimal dosage (1.0%), it ensures uniform hydration, reduces autogenous shrinkage, and enhances strength development.

- Overdosage (1.5%) can lead to undesirable effects like delayed setting, formation of weak gel-like structures, or increased porosity.

- The mechanical performance enhancement follows a non-linear trend — benefits increase up to a point (1.0%) and then slightly reduce at higher dosages.

Compressive Strength

The compressive strength of PEG-modified self-curing concrete was evaluated at 3, 7, and 28 days. A consistent strength gain was observed over time for all mixes.

- PEG 1.0% mix recorded the highest strength (26.32 MPa at 28 days), outperforming both 0.5% and 1.5% mixes.
- PEG 0.5% mix yielded the lowest values, indicating insufficient internal curing.
- PEG 1.5% mix, although higher than 0.5%, showed slightly reduced strength compared to 1.0%, suggesting a possible overdosage effect causing microstructural softening or delayed hydration.

Split Tensile Strength

The tensile strength, which is critical for concrete's cracking resistance, also followed a similar trend.

- The maximum strength (3.76 MPa at 28 days) was achieved with 1.0% PEG.
- The steep gain between 0.5% and 1.0% PEG indicates enhanced internal moisture, contributing to better cement matrix bonding.
- At 1.5% PEG, a marginal decline (3.41 MPa) was observed, again pointing toward over-saturation effects, which might lead to internal voids or plasticization.

Flexural Strength

Flexural strength results, important for assessing resistance to bending, showed improved performance with PEG.

- 1.0% PEG dosage again provided the highest flexural strength (3.59 MPa).
- Although the 1.5% PEG mix showed nearly similar strength (3.56 MPa), it did not yield any additional benefit, suggesting a plateau effect.

1.8 SUMMARY

This study investigated the performance of self-curing concrete using Polyethylene Glycol (PEG 400) as an internal curing agent and Polyethylene Terephthalate (PET) fibers as a reinforcing component in M25 grade concrete. The experimental work focused on evaluating key mechanical properties—compressive strength, split tensile strength, and flexural strength—at 3, 7, and 28 days for three dosage levels of PEG (0.5%, 1.0%, and 1.5% by weight of cement) with PET fixed at 2% by volume.

1.9 CONCLUSION

Based on the experimental findings and subsequent analysis, the following conclusions are drawn:

- PEG 400 acts as an effective self-curing agent, significantly improving the hydration process, especially at the optimal dosage of 1.0% by weight of cement.
- The compressive strength improved from 24.39 MPa (control) to 26.32 MPa for the 1.0% PEG mix at 28 days, validating the hydration enhancement hypothesis.
- The split tensile strength peaked at 3.76 MPa (1.0% PEG), demonstrating improved internal bonding due to better moisture retention.
- The flexural strength reached 3.59 MPa for the 1.0% PEG mix, confirming enhanced ductility and crack resistance
- The strength gains were less pronounced or slightly reduced at 1.5% PEG, suggesting that excessive internal curing agent may result in delayed hydration, plasticization, or void formation.
- Among all mixes, PEG 1.0% + PET 2% demonstrated the best balance of workability, strength, and self-curing effectiveness.

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