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Performance Evaluation Of Self-Curing Concrete Using Polyethylene Glycol For Enhanced Strength And Durability

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Abstract:
Self-curing is used to maintain moisture content in concrete when normal curing is impractical. This study investigates the performance of self-curing concrete using Polyethylene Glycol (PEG 4000) as a chemical admixture to maintain internal moisture during hydration. Concrete grades M20, M30, and M40 were analysed with varying PEG concentrations (0.5%, 1%, 1.5%, and 2%) to identify the optimal dosage for each grade. The results indicated that PEG improved mechanical properties with optimal concentrations of 2% for M20, 1% for M30, and 0.5% for M40 concrete. Self-curing concrete exhibited higher compressive and flexural strengths compared to traditionally cured concrete, with improvements of 7.0%, 8.3%, and 5.8% for M20, M30, and M40, respectively. The study concludes that self-curing concrete can provide practical benefits in areas with water scarcity by improving workability, compressive strength, and durability.
Keyword: *Compressive strength, Split tensile strength, Flexural strength, Poly ethylene glycol(4000, Chemical admixture.*

1.INTRODUCTION

Concrete is the most widely used construction material due to its remarkable strength, durability, and adaptability. However, the curing process, which ensures adequate hydration of cement to minimize shrinkage, cracking, and other structural defects, is critical to its long-term performance. Traditional curing methods—such as ponding, spraying, and wet coverings—are effective but often labor-intensive, time-consuming, and water-intensive. These conventional methods pose significant challenges for remote construction sites or areas with limited water availability, where improper curing can compromise the strength and durability of concrete structures [1]. Amid increasing environmental concerns, water conservation has become a priority, especially for large infrastructure projects that require significant water for curing. In this context, self-curing concrete—also known as internal curing concrete—emerges as a sustainable alternative by eliminating the need for external water sources. Through internal moisture reservoirs, this type of concrete maintains consistent hydration, ensuring even curing throughout the structure and enhancing its overall integrity [2]. The American Concrete Institute (ACI 308) supports internal curing, noting that it compensates for surface moisture loss, reduces labor, and shortens curing time by facilitating continuous hydration across the concrete matrix [3]. A key component in self-curing concrete is Polyethylene Glycol (PEG 4000), a water-soluble polymer that helps retain internal moisture and minimizes evaporation. By stabilizing moisture levels, PEG 4000 promotes early strength development, reduces permeability, and increases the durability of the concrete. It mitigates shrinkage and cracking, preventing early structural issues [4,5]. This polymer is particularly beneficial for high-strength concrete mixes, such as M30 and M40, where maintaining workability can be challenging due to low water-to-cement ratios. Additionally, PEG 4000 safeguards reinforcing steel by preventing corrosion and water ingress, thereby reducing self-desiccation and promoting long-term hydration. These properties make PEG-based self-curing concrete an ideal choice for large-scale infrastructure projects, precast elements, and construction in remote or water-scarce regions [1, 5]. This study focuses on evaluating the effectiveness of PEG 4000 in enhancing self-curing concrete for M20, M30, and M40 grades. Through experimental analysis, the work aims to identify the optimal dosage of PEG 4000 and examine its impact on the mechanical properties of concrete, such as compressive, tensile, and flexural strength. The findings will offer valuable insights into the potential of self-curing concrete to address water scarcity challenges while maintaining structural performance, making it a viable solution for sustainable construction practices.

2.Related Works

In the field of civil engineering, self-curing concrete (SCC) has gained popularity as a way to increase the strength, durability, and water retention of concrete without the need for ongoing external curing [6,7]. To avoid shrinkage fractures and guarantee proper hydration, conventional concrete needs to be regularly cured, which can be difficult in places with little access to water. By employing chemical agents such as polyethylene glycol (PEG) to increase water retention, decrease evaporation, and improve overall hydration, self-curing concrete lessens these difficulties [8]. According to research, adding PEG to concrete mixtures causes the drying process to be delayed, which increases the concrete's compressive strength [9]. Research on PEG's various molecular weights found that those with larger molecular weights are better at retaining moisture, which improves concrete's performance in arid environments [10]. PEG-200 and PEG-400 have been shown in comparative studies to be beneficial in reducing shrinkage cracks and enhancing durability [11]. Due to extended hydration, laboratory tests showed that SCC with PEG additions had improved flexural and split-tensile strength when compared to conventional mixtures [12]. A related investigation confirmed the increased durability of PEG-enhanced concrete by showing that it retained its structural integrity throughout a variety of climatic conditions, including exposure to heat and frost cycles [13]. PEG-modified concrete had lower water permeability, which lowers the danger of corrosion in reinforcement bars, according to an evaluation of SCC's water absorption behavior [14]. Additionally, the longer lifespan of concrete structures is a result of the decreased water absorption [15].The application of self-curing concrete in practical building has also been confirmed by field tests. For example, compared to conventionally cured concrete, PEG-based SCC produced better compressive strength and fewer surface fractures in bridge decks and pavements [16]. SCC is a sustainable alternative to traditional curing processes because it lowers labor and water expenses, according to research conducted on residential and commercial buildings [17]. Additionally, by using less water during construction, the enhanced hydration lowers the carbon impact [18]. Additional understanding of the hydration kinetics of SCC has been gained through numerical modeling studies, which have confirmed that PEG-modified concrete outperforms conventional concrete in terms of hydration levels during the first 28 days [19]. SCC's potential for large-scale infrastructure projects was validated by long-term durability evaluations conducted over a two-year period, which showed that it maintains compressive strength and durability without experiencing considerable deterioration [20]. SCC's mechanical qualities were further enhanced by studies that combined it with additional cementitious ingredients such fly ash and silica fume, demonstrating how versatile it is for a range of construction applications [21].By evaluating the effectiveness of SCC utilizing PEG in both controlled and field settings, this study expands on previous studies by highlighting the concrete's increased strength and durability. In order to guarantee long-lasting infrastructure development and solve the issues of few water resources, this study will offer suggestions for sustainable concrete practices in areas vulnerable to water scarcity.

3. Proposed System

In order to assess the performance of self-curing concrete augmented with Polyethylene Glycol (PEG 4000) across various concrete grades, this study uses a thorough methodology. Material selection, experimental design, specimen preparation, mixing, curing, and performance evaluation are all part of the inquiry. The binder was Ordinary Portland Cement (OPC) 53 grade, which has a specific gravity of 3.14. The fine aggregate went through a 4.75 mm screen, with a specific gravity of 2.66, a fineness modulus of 2.72, and met IS 383-1970 requirements. Coarse aggregate in 10 mm and 20 mm sizes was utilized; it had a specific gravity of 2.70 and a fineness modulus of 7.13. To aid in self-curing, different amounts of PEG 4000 were added, and fresh potable water was utilized for mixing. PEG 4000 was added to concrete grades M20, M30, and M40 at dosages of 0.5%, 1%, 1.5%, and 2% in order to evaluate performance. Material testing, concrete mix design, specimen preparation, casting, curing, and testing of hardened concrete were all part of the experimental design. While sieve analysis verified appropriate particle dispersion for conformity to the mix design, material tests used particular gravity tests to validate the accuracy of cement and aggregate densities. The methodology of the present work is represented in figure 1.

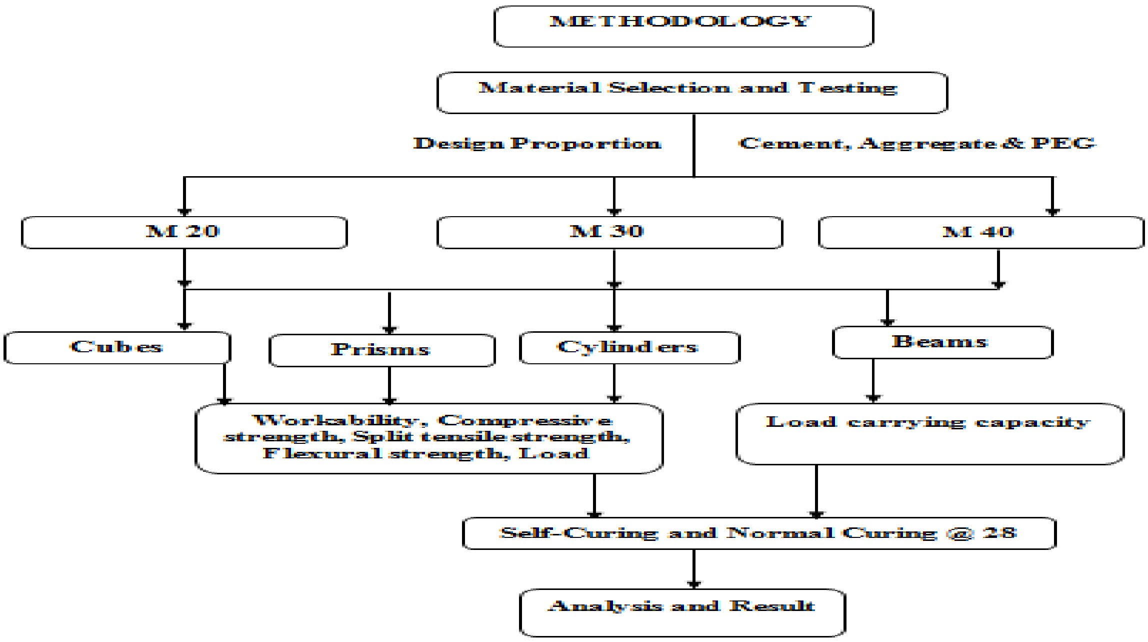

Figure1: Methodology of Present work

For M20, M30, and M40 grades, the water-to-cement ratios were determined by the concrete mix design to be 0.45, 0.40, and 0.36, respectively. The material quantities per cubic meter for each grade are listed in Table 1.1. Prisms (100 mm × 100 mm × 500 mm) for flexural strength assessments, cubes (150 mm × 150 mm × 150 mm) for figuring out the ideal PEG dosage, cylinders (150 mm × 300 mm) for split tensile strength tests, and beams (1500 mm × 150 mm × 230 mm) for load-deflection investigations were among the many specimens that were made. In order to guarantee consistency, the dry ingredients—cement, fine aggregate, coarse aggregate, and PEG 4000—were blended before water was added. To evaluate workability, tests for slump and compaction factor were conducted using a concrete mixer. To eliminate air spaces and provide adequate consolidation, the concrete mix was placed into molds and compacted using a needle vibrator. Self-curing and conventional water curing were the two methods used for curing. While self-curing specimens were maintained in a darkened setting to retain internal moisture without the need for external water application, standard curing involved submerging specimens in water for 28 days (as illustrated in Figures 1 and 2). Mechanical experiments on hardened concrete included split tensile strength tests on cylindrical specimens, flexural strength tests on prisms to gauge resistance to bending forces, and compression tests on 36 cubes to assess compressive strength after 28 days. Using a Universal Testing Machine (UTM) with two-point loading and dial gauges or deflection measurements, the load-deflection behavior of beam specimens was evaluated. Data analysis, the last stage of the approach, compared the performance of conventional and self-curing concrete. The ideal PEG 4000 dosage for every concrete grade was determined by analyzing compressive, tensile, and flexural strength values. The structural benefits of self-curing concrete in real-world applications were assessed by analyzing the load-deflection behavior of beams. This thorough method explains the benefits of self-curing concrete and proves that it works well for infrastructure projects, especially in places with scarce water supplies.

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4. RESULTS AND DISCUSSION

Through a battery of mechanical tests, the study assessed the performance of concrete of grades M20, M30, and M40. 36 cube specimens underwent compressive strength testing, while cylindrical specimens underwent split tensile strength testing. Beam specimens were put through load-deflection analysis under two-point loading, while prism specimens were used to evaluate flexural strength. The effectiveness of different PEG 4000 dosages (0.5%, 1%, 1.5%, and 2%) was examined in comparison to both normal and self-curing techniques. To guarantee uniformity in mix preparation, workability tests, such as slump and compaction factor, were performed on fresh concrete. In order to evaluate flexural performance, the study also looked at how beams behaved structurally under load.

4.1 Slump and Compaction Factor Test

The workability of concrete grades M20, M30, and M40 was assessed through slump cone and compaction factor tests. The results of Workability of Concrete are presented in Table 4.1 and represented in figure 2.

Table 4.1: Workability of Concrete

S.No	Grade of Concrete	Slump (mm) NCC	Slump (mm) SCC	Compaction Factor NCC	Compaction Factor SCC
1	M20	50	60	0.91	0.93
2	M30	40	55	0.86	0.87
3	M40	35	40	0.75	0.81

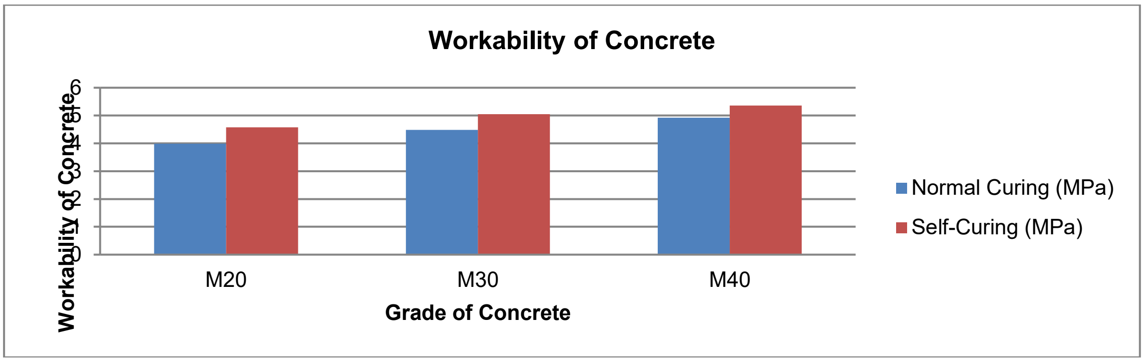

Figure 2: Depicts Workability of Concrete

In every grade, SCC has greater slump values than NCC, demonstrating better workability and flowability. Because of its simplicity of installation, mechanical compaction is no longer necessary, especially for higher grades like M30 (55 mm) and M40 (40 mm). NCC, on the other hand, requires more work in placement and compaction due to its lower slump values (50 mm for M20, 40 mm for M30, and 35 mm for M40). With greater compaction factor values (0.93 for M20, 0.87 for M30, and 0.81 for M40), SCC also exhibits superior self-compaction, which enables it to fill gaps and compact under its own weight—perfect for intricate constructions. Minimal changes in compaction factor at lower grades indicate that the benefits of SCC increase with concrete grade. The enhanced workability of SCC is ascribed to polyethylene glycol's (PEG 4000) ability to hold water, which keeps the concrete mix's moisture content stable and improves its fluidity and handling ease.

4.2 Compressive Strength

Compressive strength tests were conducted in accordance with IS: 5161999, and the results at 28 days for grades M20, M30, and M40 are given in table 4.2 and represented in Figure 3. Average Compressive Strength of M20, M30, and M40 Concrete at 28 Days.

Table 4.2 The compressive strengths results

S.No	Grade of Concrete	Compressive Strength (MPa) - NCC	Compressive Strength (MPa) - SCC
1	M20	27.36	28.28
2	M30	38.68	39.47
3	M40	48.48	49.26

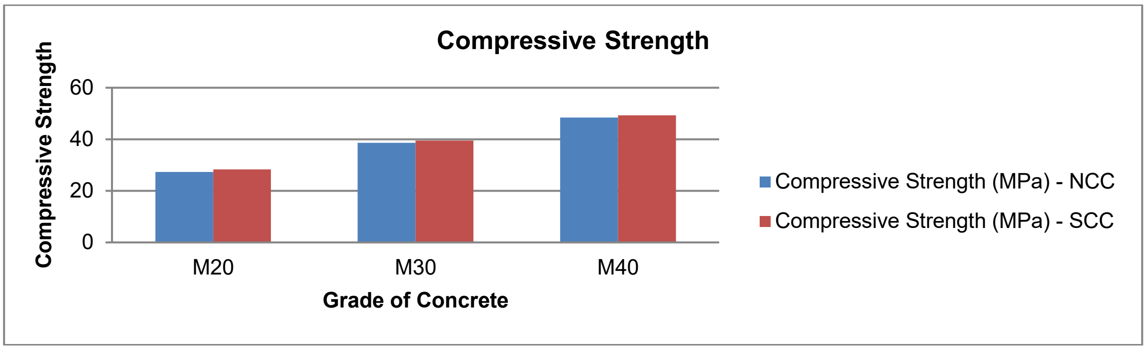

Figure 3: Depicts average Compressive Strength of M20, M30, and M40 Concrete at 28 Days

SCC and NCC perform differently, according to the 28-day compressive strength data for grades M20, M30, and M40. The compressive strengths for M20 were 28.28 MPa for SCC and 27.36 MPa for NCC. While the values for M40 were 48.48 MPa and 49.26 MPa, respectively, NCC and SCC reached 38.68 MPa and 39.47 MPa in M30. When compared to conventional curing techniques, SCC consistently demonstrated a 3.3% increase in strength. The significance of choosing the right grades was highlighted by the higher compressive strength of higher-grade concretes. Better cement particle contact and fewer voids are credited with this improvement, which is made possible by PEG's internal moisture retention that improves hydration.

4.3 Split Tensile Strength

The split tensile strength was evaluated on cylindrical specimens, and the results at 28 days are summarized in Table 4.3 and represented in figure 4.

Table 4.3: Split Tensile Strength Results

S. No	Grade of Concrete	Normal Curing (MPa)	Self-Curing (MPa)
1	M20	2.50	2.77
2	M30	3.28	3.68
3	M40	5.02	5.14

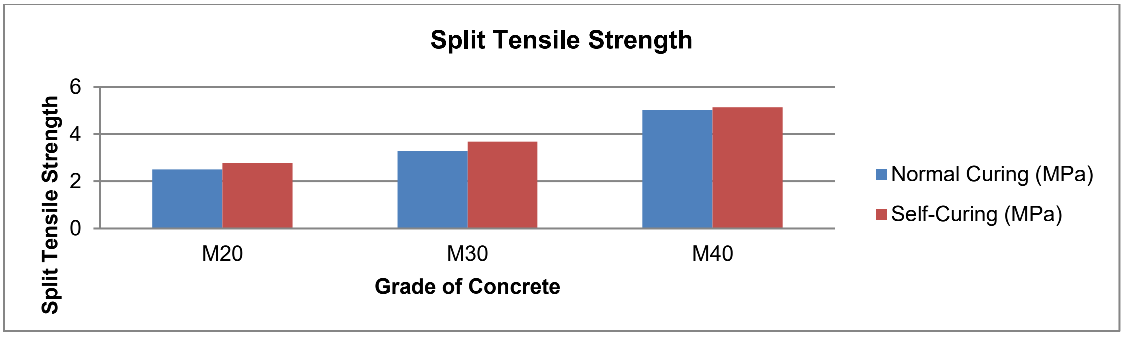

Figure 4: Depicts average Split Tensile Strength of M20, M30, and M40 Concrete at 28 Days

The 28-day split tensile strength data for M20, M30, and M40 grades show that SCC outperforms NCC. In M20, SCC achieved 2.77 MPa compared to 2.50 MPa for NCC, reflecting improved moisture retention and tensile resistance. For M30, SCC recorded 3.68 MPa, while NCC reached 3.28 MPa. In M40, the values were 5.14 MPa for SCC and 5.02 MPa for NCC. SCC demonstrated improvements of

1.11%, 1.12%, and 1.03% over NCC in M20, M30, and M40 grades, respectively. The enhanced tensile strength is attributed to PEG's moisture retention, promoting better bonding and hydration within the concrete matrix.

4.4Modulus of Rupture

Flexural strength tests conducted on prisms (150 mm x 150 mm x 500 mm) at 28 days revealed that self-curing concrete surpassed normal curing concrete in strength. The results of Average Flexural Strength of M20, M30, and M40 Concrete at 28 Days are given in table 4.4 and depicted in Figure 5.

Table 4.4: Flexural Strength Test

S. No	Grade	Normal Curing (MPa)	Self-Curing (MPa)
1	M20	3.99	4.58
2	M30	4.49	5.05
3	M40	4.92	5.36

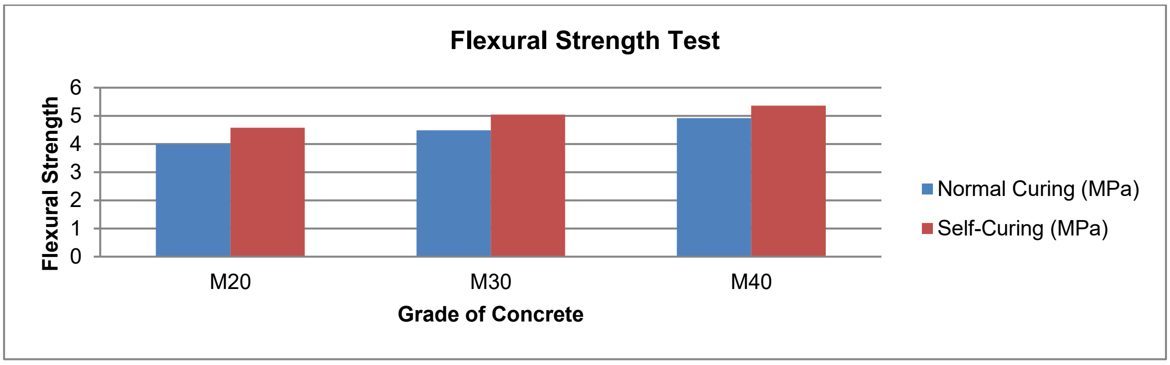

Figure 5: Depicts avg Flexural Strength of M20, M30 and M40 Concrete at 28 days

The 28-day flexural strength test shows that SCC outperforms NCC across all grades (M20, M30, and M40). SCC achieved flexural strengths of 4.58 MPa, 5.05 MPa, and 5.36 MPa for M20, M30, and M40, respectively, reflecting an improvement of 8.9% to 14.8% over NCC. This enhanced performance is attributed to SCC's ability to retain internal moisture, ensuring continuous hydration and reducing microcrack formation. The improved bonding between cement paste and aggregates further strengthens flexural performance. Although the percentage improvement is more pronounced in lower grades like M20, the consistent increase across all grades highlights SCC's effectiveness, especially where external curing is limited.

4.5 Flexural Behaviour of Reinforced Concrete Beams

The experimental investigation into the flexural behavior of reinforced concrete beams using M20, M30, and M40 grades under different curing methods shows varying performance levels. The load versus deflection curves for M40 grade concrete illustrating the beam's capacity to withstand loads before failure are depicted in figure 6 to figure 11.

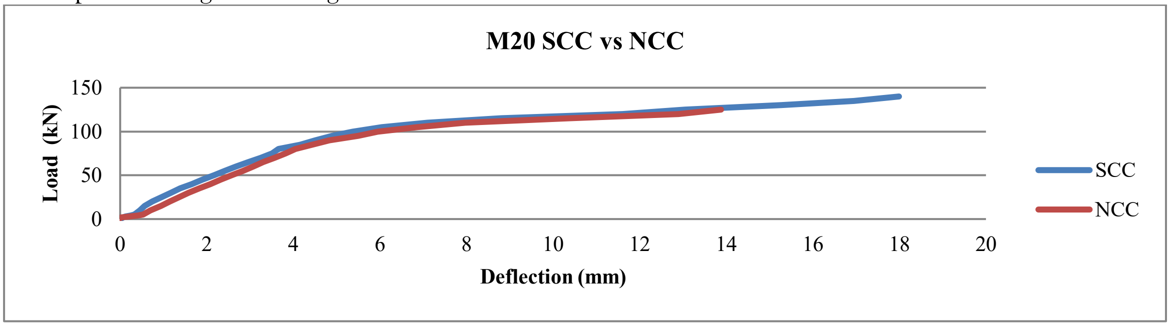

Fig.6: Depicts Load vs Deflection of M20 Grade of Concrete

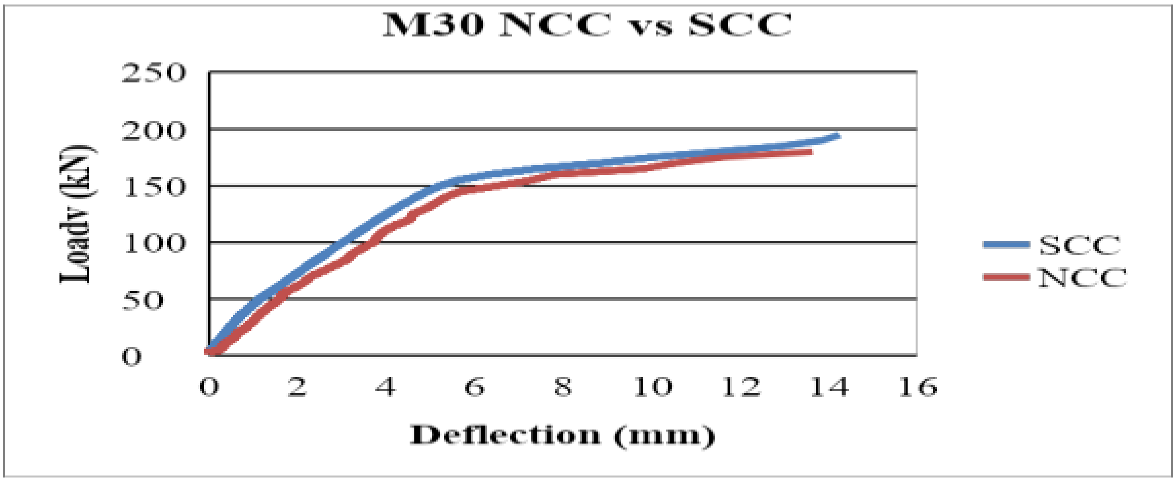

Figure 7: Depicts Load vs. Deflection of M40 Grade of Concrete

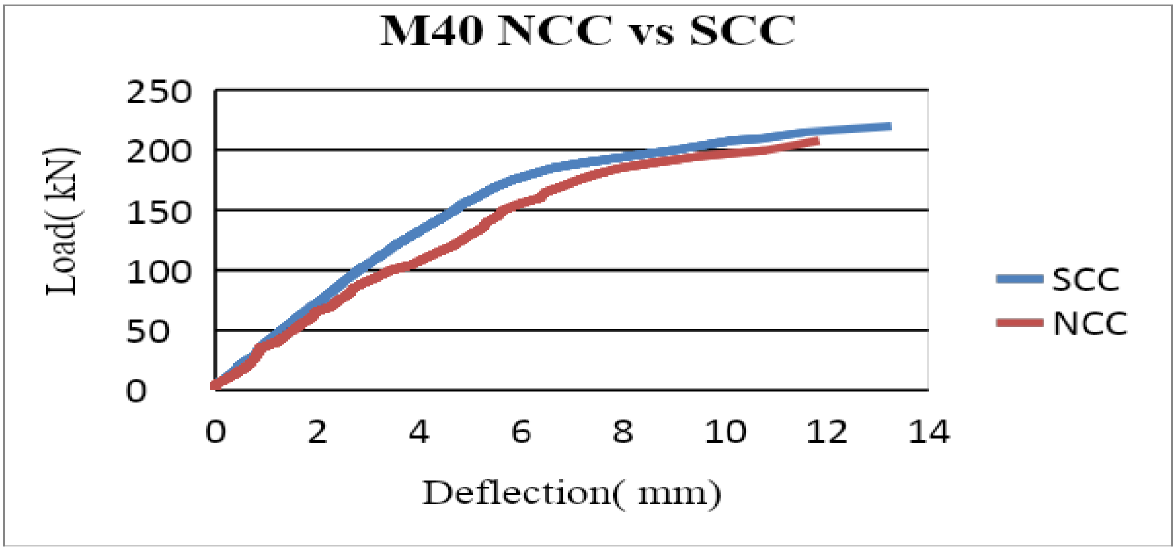

Figure 8: Depicts Load vs. Deflection of M40 Grade of Concrete

Additionally, moment versus curvature graphs for grades M20, M30, and M40 are depicted in Figures 4.7 to 4.9.

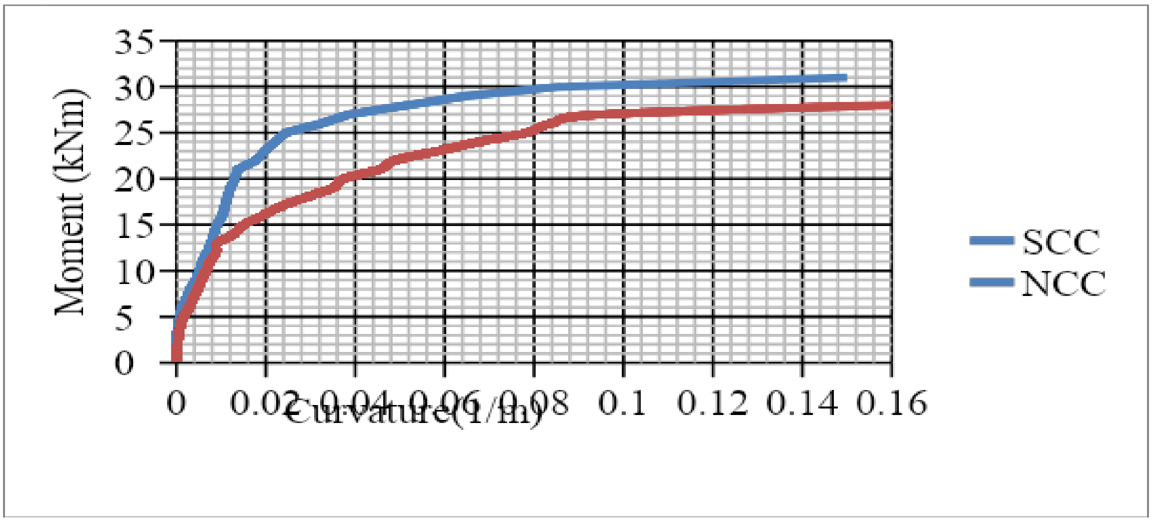

Figure 9: Depicts Moment vs. Curvature of M20 Grade of Concrete

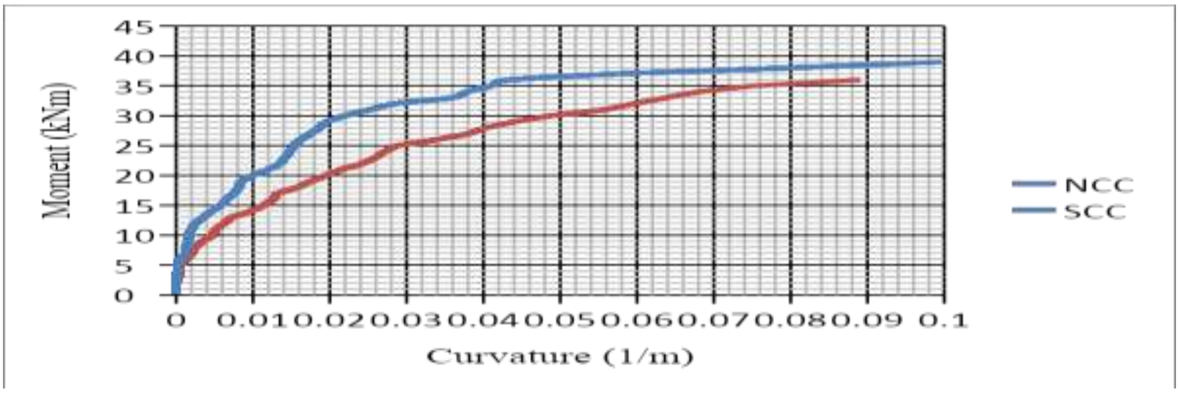

Figure 10: Depicts Moment vs. Curvature of M30 Grade of Concrete

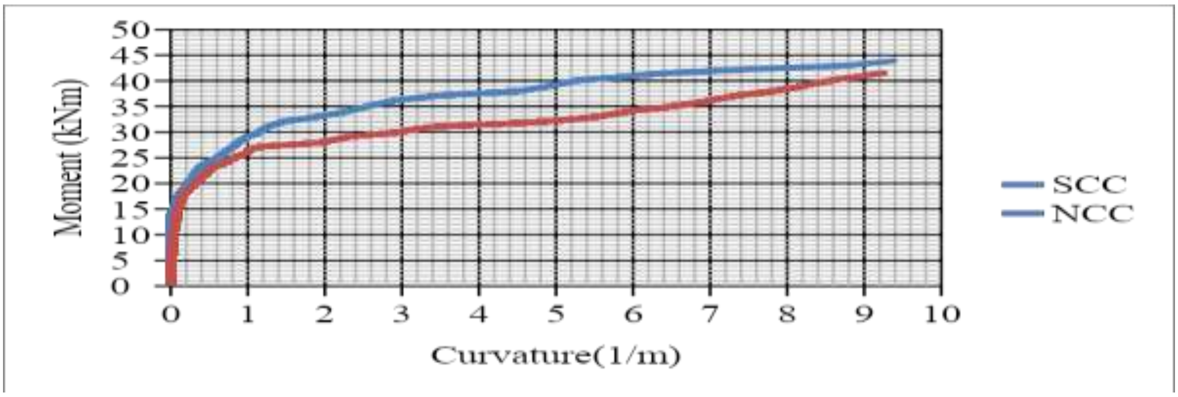

Figure 11: Depicts Moment vs. Curvature of M40 Grade of Concrete

Self-curing concrete beams show reduced deflections as compared to regular curing beams, indicating improved flexural performance and stability under loading conditions, according to the analysis of the load deflection behavior. When comparing self-curing concrete beams to regular curing concrete, the load deflection graphs show that the former had less deflections. Self-curing concrete's increased stiffness is vital in applications where structural integrity depends on deflection control. The advantages of employing PEG as a self-curing agent are further shown by the change in the neutral axis and decreased compression area at high loads. These outcomes are consistent with those of Tyagi (2016), who observed that self-curing concrete strengthens the link between the concrete matrix and steel reinforcement, increasing the overall strength and ductility of reinforced structures.

4.6Load Carrying Capacity of Beams

Different beams have different load-carrying capacities are presented in table 4.5. M20 showed initial crack loads of 13 kN for NCC and 15 kN for SCC. With a final load of 155 kN, self-curing beams outperformed NCC beams for M20 by 7.0%. The improvements for M30 (8.3%) and M40 (5.8%) were comparable. Improved internal moisture retention, which reduces early age cracking and helps to create a more even load distribution across the beam, is responsible for the increased load capacity of self-curing beams.

Table 4.5: Load Carrying Capacity of Beams

S. No.	Grade of Concrete	Normal Curing (kN)	Self-Curing (kN)
1	M20	145	155
2	M30	180	195
3	M40	208	220

5.CONCLUSION

The study found that self-curing concrete containing PEG 4000 greatly enhances its mechanical properties and durability, especially in environments with limited water supplies. The compressive, tensile, and flexural strengths of self-curing concrete were consistently greater across all classes. The largest strength increases were seen in M20 concrete, suggesting that PEG concentration plays a crucial role in performance. Additionally, because self-curing concrete can handle more weight and deflect less, it is a good alternative to traditional curing methods.

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