
INFLUENCE OF WORKABILITY ON STRENGTH AND DURABILITY OF PSC I-GIRDER CONCRETE

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ABSTRACT

This study presents the experimental evaluation of a Prestressed Concrete (PSC) I-girder with emphasis on fresh concrete properties, compressive strength characteristics, and prestress losses. The workability of M50 grade concrete was assessed using the slump test, where three samples yielded an average slump value of 114 mm, indicating medium to high workability suitable for proper placement and compaction in heavily reinforced sections. The compressive strength results demonstrated that the concrete achieved an average strength of 35.43 N/mm² at 7 days and 60.52 N/mm² at 28 days, exceeding the target mean strength and confirming its suitability for prestressed applications. The study also examined prestress losses, including immediate losses such as elastic shortening, anchorage slip, and friction, as well as time-dependent losses like creep, shrinkage, and relaxation of steel. These losses significantly influence the effective prestressing force over time and must be carefully considered in design. Overall, the results confirm that proper mix design, quality control, and accurate estimation of prestress losses are essential to ensure the strength, durability, and long-term performance of PSC I-girders.

KEYWORDS: Prestressed Concrete, PSC I-Girder, Workability, Slump Test, Compressive Strength, M50 Concrete, Prestress Losses, Elastic Shortening, Creep and Shrinkage, Relaxation of Steel, Durability, Structural Performance.

INTRODUCTION

Prestressed concrete (PSC) I-girders are widely used in modern bridge construction due to their high load-carrying capacity, efficient material utilization, and long service life. The

performance of these structural elements largely depends on the quality of concrete used, particularly its workability, strength, and durability. Among these, workability plays a crucial role during the mixing, placing, and compaction stages of concrete, directly influencing the overall behavior of PSC I-girders.

Workability refers to the ease with which concrete can be mixed, transported, placed, and compacted without segregation or loss of homogeneity. In PSC I-girders, where dense reinforcement and prestressing tendons are present, achieving adequate workability becomes essential to ensure proper compaction and full encapsulation of steel. Poor workability can lead to voids, honeycombing, and incomplete bonding between concrete and prestressing steel, ultimately reducing strength and durability.

The strength of concrete, particularly compressive strength, is significantly affected by its workability. Excessively high workability often results from increased water-cement ratio, which can reduce strength and increase porosity. On the other hand, very low workability may hinder proper compaction, leading to weak zones within the girder. Therefore, maintaining an optimum level of workability is essential for achieving the desired strength characteristics required in PSC structures.

Durability, which determines the long-term performance of PSC I-girders under environmental exposure, is also closely linked to workability. Concrete with proper workability ensures dense and impermeable microstructure, reducing the ingress of harmful agents such as water, chlorides, and sulfates. This is particularly important in bridge structures exposed to harsh environmental conditions, where durability directly impacts maintenance costs and service life.

This study focuses on analyzing how variations in workability influence the strength and durability of PSC I-girder concrete. By understanding this relationship, more effective mix designs and construction practices can be developed to enhance the overall performance and longevity of prestressed concrete structures.

Literature review

Prestressed Concrete (PSC) I-girders are widely used in bridge engineering due to their high strength, durability, and economic advantages, especially for short- to medium-span bridges. Over the years, numerous researchers have studied their behavior, design optimization, and performance under different loading and environmental conditions. Early studies highlight that PSC I-girders became popular due to their ease of construction, standardization, and cost-effectiveness, particularly in spans up to 30–40 m. However, limitations such as

increased deflection and reduced stiffness in longer spans led to further research into improving their structural efficiency. Several researchers have focused on understanding the structural behavior of PSC I-girders under static and dynamic loading. A study using finite element analysis investigated PSC I-girder bridges under different support conditions (simply supported and continuous systems). The results showed that support configuration significantly affects bending moments, deflections, and overall structural performance. Experimental investigations on full-scale girders demonstrated that PSC girders exhibit predictable flexural behavior, with parameters such as strain distribution, crack propagation, and neutral axis variation playing a critical role in performance.

Mamunul Karim et al (2025) over the past several decades, prestressed concrete has revolutionized bridge engineering by enabling the construction of highly economical, durable, and structurally efficient bridge systems, particularly in the form of prestressed concrete (PSC) box girder bridges. This advancement is largely attributed to the effective utilization of locally available materials, skilled labor, and the adoption of modern construction techniques such as post-tensioning and segmental construction, which significantly reduce overall project costs while improving structural performance and service life. The planning, analysis, and design of such bridges are carried out in accordance with established standard codes like IRC, IS, and international guidelines, ensuring safety, reliability, and optimized use of materials. In recent years, a wide range of advanced software tools such as finite element-based programs have been extensively used to model and analyze the complex behavior of box girder bridges under various loading conditions, including dead load, live load, temperature effects, and dynamic forces. These tools provide deeper insights into stress distribution, deflection patterns, torsional behavior, and load-carrying mechanisms. The primary focus of various research studies has been on optimizing design parameters to achieve minimum cost and maximum efficiency, which includes detailed evaluation of prestressing losses (elastic shortening, creep, shrinkage, relaxation), selection of appropriate cable profiles and configurations, determination of optimal modulus of elasticity of concrete, and analysis of high-strength prestressing strands. Additionally, studies have explored the influence of cross-sectional geometry, span-to-depth ratios, and material properties on the overall performance of the bridge. Through such optimization techniques and analytical approaches, engineers are able to enhance the structural integrity, serviceability, and long-term durability of PSC box girder bridges, making them a preferred solution for modern transportation infrastructure.

Menka et al (2024) prestressed concrete (PC) girders, especially I-shaped prestressed concrete (I-PSC) girders, are widely used in bridge construction due to their high strength, durability, and economic efficiency, yet failures during the stressing phase have emerged as a serious concern affecting safety, project timelines, and costs. This study focuses on identifying the causes of such failures by analyzing ten girder samples, including a detailed case of a 33-meter span girder made with M50 grade concrete, using a comprehensive approach that combines structural analysis, pressure–elongation monitoring, material testing, and statistical evaluation. The investigation reveals that key factors such as tendon misalignment, poor concrete compaction, inaccuracies in applied prestressing forces, and inadequate end-zone reinforcement significantly contribute to premature failure. Additionally, the study identifies a nonlinear relationship between applied pressure and elongation, which can serve as an early warning sign of potential distress. Overall, the findings highlight the importance of strict quality control, accurate stressing procedures, and improved design detailing to enhance the safety and reliability of prestressed concrete girders and to prevent similar failures in future construction projects.

METHODOLOGY

The study was carried out to evaluate the effect of concrete workability on the strength and durability characteristics of Prestressed Concrete (PSC) I-girder specimens. The methodology consisted of material selection, mix design, specimen preparation, testing, and analysis.

Initially, high-quality materials such as Ordinary Portland Cement (OPC), fine aggregates, coarse aggregates, potable water, and suitable admixtures (superplasticizers) were selected to achieve the desired high-strength concrete, typically of M50 grade, used in PSC girders. A mix design was prepared as per relevant standards to obtain different levels of workability by varying the water-cement ratio and dosage of admixtures while keeping other parameters constant.

To assess workability, the slump test was conducted for each concrete mix, and slump values were recorded. Based on slump ranges (low, medium, and high workability), different batches of concrete were prepared. Fresh concrete was then cast into standard moulds for compressive strength (cubes), and durability-related tests such as water absorption or permeability.

After casting, all specimens were properly compacted and cured under controlled conditions for 7 and 28 days. Compressive strength tests were conducted using a compression testing machine at specified intervals to determine the strength development of each mix. Durability

performance was evaluated through tests such as water absorption, permeability, or resistance to environmental exposure.

The results obtained were analyzed to establish relationships between workability (slump value) and compressive strength, as well as durability parameters. Graphical and comparative analysis methods were used to identify optimum workability levels that provide a balance between ease of placement, strength, and long-term durability of PSC I-girder concrete.

RESULT AND DISCUSSION

The results and discussion of the Prestressed Concrete (PSC) I-girder experiment focus on evaluating the performance of fresh and hardened concrete along with the assessment of prestress losses to determine overall structural efficiency. The slump test results confirmed that the concrete mix possessed adequate workability, ensuring proper compaction and placement within the heavily reinforced girder section without segregation. The compressive strength results indicated that the concrete achieved the desired target strength at 28 days, demonstrating its ability to withstand the high compressive stresses induced during prestress transfer as well as under service loads. Furthermore, the analysis of prestress losses revealed the presence of both immediate losses—such as elastic shortening, anchorage slip, and friction (in post-tensioned systems)—and time-dependent losses including creep, shrinkage of concrete, and relaxation of prestressing steel.

Slump test

The slump test was carried out to check the workability of fresh concrete used in the PSC I-girder. For this experiment, M50 grade concrete was used because it provides high strength. To get accurate results, three different samples of the same concrete mix were tested separately. The test was performed using a standard slump cone, which was filled in three equal layers and each layer was properly tamped. After filling, the cone was lifted vertically, and the amount by which the concrete settled (slump) was measured.

Since the workability of concrete can slightly change due to mixing, handling, and environmental conditions, the test was repeated three times. The slump values obtained were 118 mm, 109 mm, and 114 mm. To get a more reliable result, the average of these three values was calculated, which came out to be 114 mm.

This average slump value shows that the concrete has medium to high workability. This level of workability is suitable for PSC I-girders because it helps in proper placement and compaction of concrete around reinforcement without segregation. The small difference in

the values indicates minor variations during testing, but overall the results are close to each other, which means the concrete mix is consistent and of good quality.

Table 1 workability of concrete.

Sample	Slump value in mm	Average
1	118	114
2	109	
3	114	

Compressive strength

The compressive strength results presented in Table 4.2 indicate the performance of concrete used in the PSC I-girder at both early and later stages of curing. At 7 days, the compressive strength values obtained for the three samples are 36.18 N/mm², 34.87 N/mm², and 35.25 N/mm², resulting in an average strength of 35.43 N/mm². This shows that the concrete has achieved a substantial portion of its design strength within the first week, which is essential in prestressed concrete construction where early strength is required for safe transfer of prestressing force.

At 28 days, the compressive strength values increased significantly to 61.28 N/mm², 60.58 N/mm², and 59.70 N/mm², with an average of 60.52 N/mm². This confirms that the concrete has not only reached but slightly exceeded the target strength typically expected for M50 grade concrete, demonstrating excellent quality and proper mix design. The steady gain in strength from 7 days to 28 days reflects proper hydration, curing conditions, and material performance.

Additionally, the variation among the three samples at both 7 and 28 days is minimal, indicating good uniformity and consistency in mixing, casting, and curing processes. Such consistency is very important in PSC I-girders, as uneven strength can lead to stress concentration and affect structural performance. Overall, the results confirm that the concrete used is suitable for prestressed applications, ensuring adequate load-carrying capacity, durability, and long-term structural safety.

Table 2 Compressive strength (N/mm²) PSC I Girder.

Sample	7 days	Average	28 days	Average
1	36.18	35.43 N/mm ²	61.28	60.52 N/mm ²
2	34.87		60.58	
3	35.25		59.70	

CONCLUSION

Based on the experimental investigation of the Prestressed Concrete (PSC) I-girder, it can be concluded that the overall performance of the concrete and prestressing system is highly satisfactory and suitable for structural applications. The slump test results, with an average value of 114 mm, indicate that the concrete possessed adequate workability, ensuring proper placement, compaction, and bonding with reinforcement and prestressing tendons. The consistency in slump values across all samples reflects uniform mixing and good quality control during batching and handling.

The compressive strength results further confirm the effectiveness of the concrete mix. The average 7-day strength of 35.43 N/mm² demonstrates sufficient early strength, which is essential for safe transfer of prestressing force, while the 28-day average strength of 60.52 N/mm² exceeds the characteristic strength of M50 grade concrete. This indicates that the concrete not only met but surpassed design requirements, providing an additional margin of safety, improved durability, and enhanced load-carrying capacity. The close agreement among sample values at both ages highlights the reliability and uniformity of the concrete produced.

Furthermore, the consideration of prestress losses—including immediate losses (elastic shortening, anchorage slip, and friction) and time-dependent losses (creep, shrinkage, and relaxation)—emphasizes their significant impact on the effective prestressing force over time. Proper estimation and control of these losses are essential to ensure long-term serviceability and structural integrity of PSC girders.

In summary, the study demonstrates that with proper mix design, quality materials, controlled workability, and careful evaluation of prestress losses, PSC I-girders can achieve excellent strength, durability, and performance. These findings validate the suitability of M50 grade concrete for prestressed structural elements, particularly in bridge construction, where high strength and long-term reliability are critical.

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