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Enhancing Durability of Concrete Structures using Control Permeable Formwork Liners

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ABSTRACT

Durability is one of the most critical aspects of concrete structures, as it determines their long-term performance, safety, and sustainability. Conventional formwork systems often result in poor surface quality and increased permeability, which accelerate deterioration mechanisms such as chloride ingress, carbonation, and freeze–thaw damage. Controlled Permeable Formwork (CPF) liners offer an effective solution by allowing the removal of excess water and air from the concrete surface during casting, leading to denser, less porous, and more durable concrete cover zones. This paper investigates the role of CPF liners in enhancing the mechanical properties and durability performance of concrete, with particular emphasis on compressive, tensile, and flexural strength improvements when using supplementary cementations materials such as fly ash. The study highlights the significant reduction in permeability, improved resistance against aggressive environmental conditions, and extended service life of structures achieved through CPF application. Overall, CPF technology demonstrates high potential for sustainable construction practices, ensuring both performance efficiency and cost-effectiveness in modern infrastructure.

Keywords: Concrete durability, Controlled Permeable Formwork (CPF), Fly ash, Permeability reduction, Compressive strength, Surface quality, Sustainable construction

Introduction

Concrete is the most widely used construction material in the world, yet its long-term durability is often compromised by defects that arise during casting and curing. One of the major factors influencing durability is the quality of the concrete surface zone, which serves as the first line of defense against aggressive environmental agents such as chlorides, sulfates, carbonation, and moisture ingress. Traditional impermeable formwork systems often trap excess water and air at the concrete–formwork interface, resulting in a weak and porous surface layer with high permeability and reduced strength. To overcome this limitation, Controlled Permeable Formwork (CPF) liners have been developed as an innovative solution. CPF liners allow excess water and entrapped air to drain away during casting, thereby enhancing the density, strength, and durability of the concrete surface zone. By improving surface quality, CPF liners significantly reduce the ingress of harmful agents, extend the service life of structures, and minimize maintenance costs. Their application is particularly beneficial in aggressive environments, such as marine structures, bridges, and water-retaining structures, where enhanced resistance to deterioration is critical.

Vishal Ambad et al (2022) The study highlights the importance of improving the surface quality and durability of concrete structures by using Controlled Permeability Formwork (CPF) liners, which are designed to allow excess water and air to escape during casting while preventing the loss of cement fines and smaller particles. In this experimental work, concrete specimens were prepared using both impermeable steel formwork (SF) and CPF liners to compare their performance. The mix was designed with Ordinary Portland Cement (OPC) 53 grade**,** supplementary cementations materials such as pulverized fly ash (PFA) and micro silica**,** along with crushed sand, natural aggregates, water, and a super plasticizer to achieve workability and durability. The specimens, cast in both cubic and cylindrical shapes, were tested at 7 days and 28 days to determine their compressive strength and resistance to chloride ingress using the Rapid Chloride Penetration Test (RCPT)**.** Results showed that specimens cast with CPF liners developed a much denser and stronger cover zone because the liner facilitated the drainage of excess water and trapped air voids from the surface concrete, thereby improving the microstructure. This improvement led to a significant increase in strength, with CPF liner-cast specimens recording around 14% higher compressive strength compared to those made with impermeable steel formwork. Moreover, in terms of durability, CPF liner specimens exhibited 9.98% fewer charges passed in RCPT**,** which directly indicates lower permeability and better resistance to chloride ion ingress. Since chloride penetration is a major cause of reinforcement corrosion and long-term deterioration of concrete in aggressive environments, the findings prove that CPF liners not only improve mechanical properties but also substantially enhance the durability of concrete, making them highly effective for construction in marine and chloride-rich environments.

S. Kothandaraman et al. (2016) carried out an experimental study to evaluate the effect of Controlled Permeable Formwork (CPF) liners on the surface hardness and wear resistance of concrete by comparing specimens cast against CPF liners with those cast against impermeable steel formwork (IMF). The results demonstrated that the use of CPF liners significantly improved the surface quality of concrete, with an enhancement in surface hardness ranging from 14% to 58% compared to conventionally cast specimens. A key observation was that in CPF-cast concretes, the outer 20 mm thick cover layer exhibited greater hardness than the core concrete, indicating superior densification and durability of the surface region. In contrast, for concrete cast using traditional steel formwork, the 15 mm thick cover zone was found to be softer than the core, reflecting poorer surface quality and greater susceptibility to deterioration. This beneficial effect of CPF liners on enhancing the near-surface properties of concrete was consistent across water-to-cement ratios ranging between 0.31 and 0.48, confirming the robustness and reliability of CPF liners in improving the long-term performance of cover concrete.

Methodology

The methodology for enhancing the durability of concrete structures using Controlled Permeable Formwork (CPF) liners involves a systematic approach beginning with the selection of suitable materials, including Ordinary Portland Cement (OPC) partially replaced with fly ash at varying percentages (0%, 5%, 10%, 15%, and 20%), fine and coarse aggregates, and potable water. CPF liners, which are permeable sheets made from geotextile-type fabric, are fixed on the inner faces of the formwork before casting to allow controlled drainage of excess water and air voids from the fresh concrete surface. Concrete mixes are prepared and placed into both conventional formwork (without CPF) and CPF-lined formwork to ensure comparative evaluation. During casting, the CPF liners act as filters, preventing cement fines from escaping while removing surplus water and entrapped air, thereby improving the quality of the cover zone by reducing porosity, increasing density, and enhancing the bond between paste and aggregate. After curing for standard durations (7, 14, and 28 days), specimens are tested for compressive strength, split-tensile strength, and flexural strength, along with durability indicators such as water absorption, permeability, and sorptivity. The results from CPF-cast specimens are then compared with those cast in conventional formwork to assess improvements in strength and durability. This methodology demonstrates that CPF liners significantly enhance surface quality, resistance to cracking, and long-term durability of concrete structures, especially when combined with fly ash replacement, which contributes to sustainability by reducing cement usage.

Result and discussion

The experimental investigation revealed that the use of Controlled Permeable Formwork (CPF) liners significantly improved the mechanical and durability properties of concrete compared to conventional formwork. Compressive, tensile, and flexural strength tests conducted at 28 days demonstrated higher values for CPF-cast specimens across all replacement levels of cement with fly ash. For compressive strength, concrete with CPF showed a consistent improvement of 15–20% over conventional concrete, with the maximum strength observed at 15% fly ash replacement, indicating an optimal balance between cement reduction and supplementary pozzolanic activity. Similarly, tensile strength exhibited a 12–16% increase in CPF specimens, highlighting the beneficial effect of reduced surface porosity and improved microstructure. Flexural strength followed the same trend, with CPF-cast specimens outperforming conventional ones by 7–10%.

In terms of durability, CPF liners effectively drained excess water and air voids from the concrete surface during casting, resulting in a denser, less permeable outer layer. This enhanced the resistance of CPF concrete to water absorption, carbonation, and chloride penetration, which are critical factors influencing long-term performance. The reduced permeability in CPF-cast concrete not only improved mechanical strength but also minimized shrinkage and cracking potential, contributing to the overall structural durability. Furthermore, the surface finish of CPF concrete was observed to be superior, with fewer defects and enhanced aesthetic quality, which reduces maintenance needs.

The inclusion of fly ash in combination with CPF further contributed to sustainability, as it reduced cement usage while maintaining or improving performance. The synergistic effect of CPF liners and fly ash replacement confirmed that CPF technology can be an efficient and cost-effective method for enhancing durability, reducing lifecycle costs, and extending the service life of reinforced concrete structures.

Compressive strength

Concrete cast using Controlled Permeable Formwork (CPF) generally exhibits higher compressive strength compared to conventional formwork due to improved surface quality and reduced near-surface porosity. CPF liners are designed to allow excess water and air to escape during casting, which enhances the consolidation and compaction of concrete at the interface with the formwork. This results in a denser and more uniform concrete near the surface, reducing micro-voids and capillary pores, which are often initiation points for cracks and deterioration. Consequently, concrete with CPF shows better mechanical performance**,** including higher compressive strength, improved durability, and reduced permeability.

Table 1 Compressive strength in N/mm^2

% Replacement	**After 28 days with CPF**	**After 28 days without CPF**	% Deduction
0	26.89	24.31	9.6
5	28.42	25.98	8.6
10	30.13	27.67	8.2
15	31.54	29.14	7.6
20	28.67	26.87	9.8

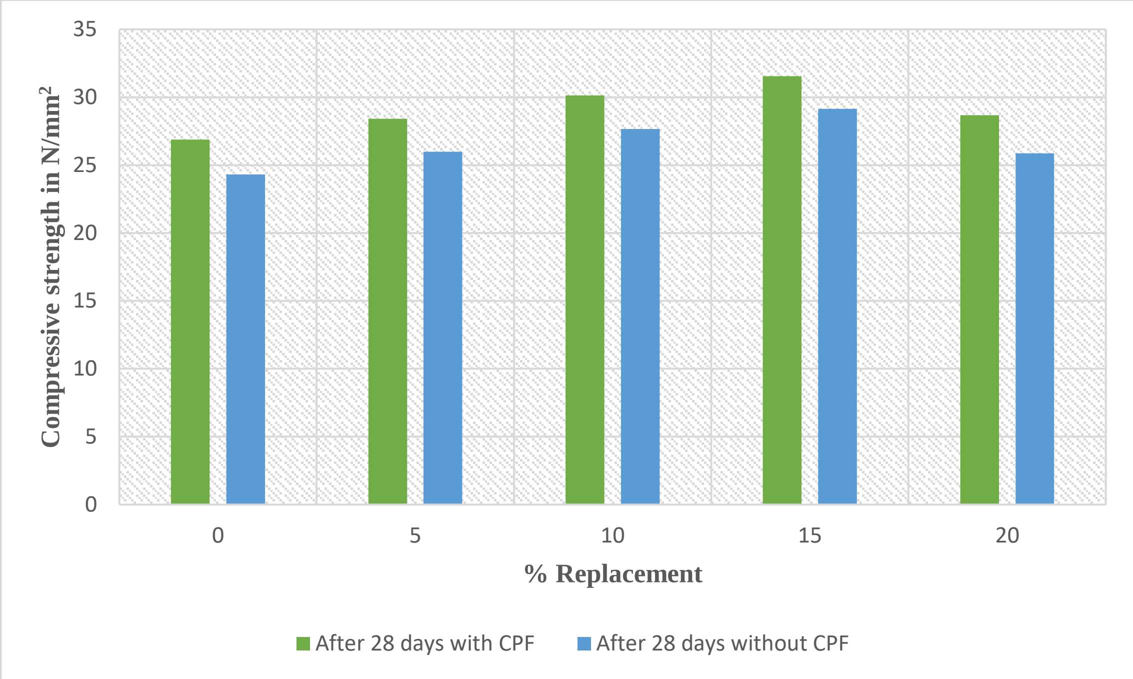

Figure 1 Compressive strength result compression

The results clearly indicate that the use of Controlled Permeable Formwork (CPF) enhances the flexural strength of concrete across all percentages of fly ash replacement when compared to concrete cured without CPF. At 0% replacement, the strength increased from 24.31 MPa without CPF to 26.89 MPa with CPF, showing a 9.6% improvement. Similarly, at 5%, 10%, and 15% replacement, the strength gains were 8.6%, 8.2%, and 7.6% respectively, highlighting a consistent improvement due to the better hydration and denser microstructure achieved through CPF. Even at 20% replacement, CPF-treated concrete exhibited higher strength (28.67 MPa) than the control mix (26.87 MPa), though the percentage improvement was slightly higher at 9.8%. Overall, the data demonstrate that CPF significantly contributes to improved flexural performance of concrete, ensuring better durability and load-bearing capacity even when cement is partially replaced with fly ash.

Conclusion

The use of Controlled Permeable Formwork (CPF) liners has proven to be an effective technique for significantly enhancing the durability of concrete structures. By allowing excess water, air voids, and laitance to escape during casting, CPF improves the quality of the concrete cover zone, resulting in higher density, reduced porosity, and improved resistance to aggressive environmental conditions. The improved surface layer not only enhances compressive, tensile, and flexural strengths but also minimizes permeability, chloride ingress, carbonation, and freeze–thaw damage, which are the main causes of premature deterioration. Furthermore, CPF contributes to increased service life, reduced maintenance costs, and better long-term performance of concrete structures. Hence, incorporating CPF liners during construction is a sustainable and cost-effective solution for achieving durable, resilient, and low-maintenance infrastructure.

References

1. Kandasamy Selvaraj and Kothandaraman Sivanandam, Influence of Controlled Permeable Formwork Liner on the Service Life of Reinforced Concrete, J. Mater. Civ. Eng., 2021, 33(6): 04021103.

2. S. Kandasamy, S. Kothandaraman, The efect of formwork liner on the service life of self-compacting concrete, Asian Journal of Civil Engineering (2020) https://doi.org/10.1007/s42107-020-00272-

3. S. Kandasamy , S. Kothandaraman, Influence of controlled permeable formwork liner on surface quality of self - compacting concrete, Construction and Materials 260 (2020) 119756.

4. Cuicui Chena*, Jianzhong Liu a, Gong Cui a , Jiaping Liu (2012) "Effect of controlled permeable formwork on the improvement of concrete performances" Elsevier: Procedia Engineering 27 (2012) 405 – 411

5. W. F. Price* and S. J. Widdows* "The effects of permeable formwork on the surface properties of concrete" Magazine of Concrete Research, 1991

6. Vishal Ambad, Raju Narwade, Karthik Nagarajan (2021) "Impact of controlled permeable formwork liner against chloride penetration on the concrete structure" Research on engineering structures and materials.

7. E. Nolan, A. M. Basheer and A. E. Long "Effects of three durability enhancing products on some physical properties of near surface concrete" Construction and Building Materials, Vol. 9, No. 5

8. A.Balasaikumar1, Dr.K.Thulasirajan (2022) "Experimental investigation on Controlled Permeable Formwork Liner in steel fibre reinforced concrete" International Research Journal of Engineering and Technology (IRJET) Volume: 09 Issue: 08

9. IS 10262 (2009) -Indian standard guidelines for mix proportion.