An Experimental Investigation on Lightweight Concrete Using Surface Improvement Liner

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ABSTRACT: Lightweight concrete may be defined as the concrete of substantially lower unit weight than that made from gravel or crushed stone. Surface improvement liner represents the controlled permeable formwork (CPF) liner is an innovative material used to improve the quality of the cover region, by allowing the air bubbles and mix-water to drain out from the surface of concrete whilst retaining cement and other fine particles. Accordingly, this not only minimises the porosity of the surface area of concrete, but it also helps towards improving or enriching the actual content. This paper reports an experimental study carried out to investigate the effect of liner on strength properties of lightweight concrete. The results showed that there is significant improvement in the strength and near surface concrete quality in CPF liner than that of conventional lightweight concrete.

KEYWORDS: Controlled permeable formwork (CPF) liner, cover region, Lightweight concrete, porosity, strength

I. INTRODUCTION

Lightweight concrete has extreme importance to the construction industry. This light weight concrete not only results in reducing dead weights on structure, but also has a better insulation against heat and sound. The utilization of industrial waste as a construction material is a big leap towards sustainable development. Flyash is a waste material obtained from thermal power plants during combustion of pulverized coal. The fundamental production process of the artificial aggregates from flyash mainly consists of three stages- mixing of raw materials, pelletization and hardening Sintered flyash is a lightweight aggregate which had been used for making lightweight concrete.

The service life of any reinforced concrete is dependent upon the superior nature of concrete and its overall quality and excellence as a suitable cover material. Concrete acting as cover material is the only means by which destructive agents or other elements can access or infiltrate the structure resulting in corrosive damage to the rebar and causing other types of damage to occur. As a liner, the controlled permeable formwork (CPF) is an active technique that enhances concrete as a cover material. As per Construction Industry Research and Information Association (CIRIA) report, the controlled permeable formwork liner can be defined as “a manufactured formwork liner that allows the passage of water and entrapped air from the concrete, and through the formwork, whilst retaining cement and other fine solids” [Price 2000]. Moreover, this liner allows for air and water that is trapped inside to drain or spill out from the surface area of concrete whereas retaining small particles and cement. CPF liner maintains adequate humidity to nurture hydration of cement particles thereby the covercrete becomes denser, stronger and less porous.

II. LITERATURE REVIEW

Kandasamy Selvaraj et al. (2021) demonstrated the effect of CPF liner with respect to the durability properties and service life of reinforced strengthened concrete. In this study experimental tests were then conducted at different stages to determine rapid chloride penetration, chloride ingress, chloride diffusion, and accelerated rebar corrosion. The found that the CPF concrete acquired excellent resistance against the ingress of chloride ions ranging between 47% and 80%. Furthermore, the results showed that the service life of concrete cast against CPF liner was extended by around 2.1 times compared to IMF concrete.

S. Kandasamy et al. (2020) investigated the influence of CPF liner concerning the durability properties and the service life of reinforced/strengthened self-compacting concrete (SCC). They conducted the experiments at different stages in order to examine accelerated rebar corrosion, rapid chloride penetration, chloride ingress, chloride diffusion and the experimental investigations revealed that CPF concrete acquired excellent resistance against the ingress of chloride ions ranging between 54 and 75%. Furthermore, the results showed that the service life of self-compacting concrete cast against CPF liner was extended by around 1.5 times as compared to IMF concrete.

Sahil Garg et al. (2019) studied the properties of near surface concrete (NSC) by the use of a commercially available CPF liner, and comparing the performance of more easily available and cheaper alternatives to CPF liner used. They performed the tests such as rapid chloride permeability test, AgNO3 colorimetry test, initial surface absorption test and pull off test to study durability properties of near surface concrete(NSC). The results showed that commercially manufactured CPF produces better surface than the particle board and gunny bag, the improvement in NSC properties by use of gunny bag is also noteworthy.

S. Kandasamy et al. (2020) studied the influence of CPF liner concerning the resilience of surface quality properties of self- compacting concrete (SCC). The experimental tests were then conducted at different stages in order to determine rebound number, dynamic hardness number, superficial Rockwell hardness number, wear resistance and abrasion resistance. They found that the CPF concrete acquired excellent resistance against the abrasion resistance ranging between 46% and 60% and the results showed that by the application of CPF liner, the cover concrete (thickness: 20 mm) turned harder, when compared to core concrete. The cover concrete (thickness: 15-mm) turned softer than core concrete in conventional cast concrete.

S. Kothandaraman et al. (2016) investigated the effect of CPF liner on the surface hardness and wear of concretes. They prepared the suitable size specimens were cast against CPF liner and (impermeable) steel formwork (IMF) and tested at various ages. In this study, the results revealed that the surface quality/hardness of CPF concretes enhanced by 14% - 58% and it was ascertained that due to CPF liner, 20 mm thick cover concrete was found to be harder than the core concrete. In conventionally cast concrete, 15 mm thick cover concrete was found to be softer than the core concrete. This change in the quality of cover concrete was found to be consistent over the w/c ratio of 0.31 to 0.48.

S. Kothandaraman et al. (2016) investigated the influence of CPF liner on the strength and certain mechanical properties of concrete with three different water–cement (w–c) ratios. In this study, the specimens were prepared against CPF liner and impermeable steel formwork (IMF) and tested at various ages starting from 7 to 365 days. They conducted the various tests to assess the surface quality; compressive, split tensile and flexural strengths, rebound hammer and abrasion resistance of concrete. The results indicated that CPF concrete performed better than IMF concrete in all aspects. They found that the use of CPF liner has significantly improved the tensile strength (say, 20 %) of concrete and the abrasion resistance has been enhanced to a remarkable level (50–80 %). Further, the surface quality is very essential to assess the cube strength of concrete and the existing testing method slightly underestimates the cube strength.

S. Kothandaraman et al. (2016) conducted an experimental study to verify the performance and efficiency of CPF liner against self-compacting concrete (SCC). In this study, suitable size specimens were prepared using impermeable formwork (IMF) and CPF liner as well. They carried out the tests to check compressive, split tensile strength and flexural strength; ultrasonic pulse velocity and rebound hammer; abrasion resistance, sorptivity and water absorption. They found that CPF liner performs equally well with SCC. Vibration/hydrostatic pressure may not play significant role in draining the interface water through CPF liner.

Wael A. Megid et al. (2018) evaluated the effect of rheology of self-consolidating concrete and super workable concrete on formed surface quality. In this study a total 31 mixtures with different 12 workability and rheological properties were cast in a specially designed Z-shaped column without any mechanical consolidation. They evaluated the surface defects, including surface air voids, signs of bleeding, segregation, and low filling ability using a proposed image analysis methodology. They found that surface defects resulting from segregation with flowable concrete with plastic viscosity lower than 10 Pa.s and yield stress lower than 100 Pa.

Wael A. Megid et al. (2020) evaluated the effect of the forming materials on surface quality of the self-consolidating and highly workable concretes. In this study, mixtures were placed in a Z-shaped mould and no mechanical consolidation was applied at all. The sides of the mould were built up using plywood, PVC, steel, and permeable formwork liner using a polyester filter. They found that the permeable lined formwork was shown to provide an effective way for the entrapped air/water bubbles and the bleed water to escape. The maximum surface dimension of the voids found on the concrete surfaces was limited to 3, 6, 7, and 10 mm for the mixtures cast using the permeable liner, steel, PVC, and plywood formwork materials, respectively.

Jiaping Liu et al. (2013) studied the effect of CPF on the water adsorption property of concrete. In this study, surface appearance, meso-surface morphology and microstructures of concrete blocks were characterized to analyze the affecting mechanism of CPF on concrete adsorption. It was found that, by applying CPF, concrete permeability was markedly reduced due to the improved surface and microstructures. In addition, the surface structure of the CPF liner was studied by SEM. It was indicated that the CPF was a beneficial and promising material for the improvement of concrete performances.

Helena Figueiras et al. (2009) investigated the full size precast elements with both self-compacting concrete (SCC) and conventional vibrated concrete (CC) using controlled permeability formwork (CPF). In this study, they compared the performance of two different CPF systems and also assess the combined effect of using CPF on SCC compared to CC.

P.J. Schubel et al. (2008) investigated the influence of concrete mixes and commonly used mineral additions and their effects on the near surface performance of vertically cast concrete against controlled permeable formwork (CPF). They found that the surface quality was dramatically improved in each case and changes to surface colour through densification were quantified. Near surface performance studies indicated a significant improvement for all systems studied.

J. Sousa Coutinho (2003) presented a laboratory study of controlled permeability formwork (CPF) applied to concrete where cement was partially replaced (10%, 15% and 20%) with Portuguese rice husk ash (RHA). They carried out the various tests to evaluate the durability of concrete made with RHA at 10%, 15% and 20% replacement of cement by weight and cast with both the usual formwork and CPF. They found that the results lead to the conclusion that CPF enhances concrete performance even further when using partial cement replacement by RHA.

S.K. Patel et al. (2019) investigated the durability and microstructural characteristics of lightweight concrete prepared by using fly ash cenosphere (FAC) and sintered fly ash aggregate (SFA) as replacements of natural fine and coarse aggregate respectively. They found that the durability results that on one hand, the strength loss in concrete caused by sulphate attack and acid attack increases with increase in percentages of individual and combined substitution of FAC and SFA and hence, the concrete comprising FAC and SFA is not suitable for the structures exposed to acidic environments. On the other hand, when FAC or SFA or both of these contents increases, the depth of chloride ingress decreases, exhibiting better performance in saline environments than the concrete mix without FAC and SFA.

Manu S Nadesan et al. (2017) established a new mix design procedure for the development of sintered fly ash lightweight aggregate concretes. In this study, the proposed methodology has been validated by developing a spectrum of concretes having water cement ratios varying from 0.25 to 0.75. The results showed that the development of 2 70 MPa concrete is possible by using cement alone without any additives. Also, it is ensured that all the concretes have densities less than 2000 kg/m^3.

Manu S. Nadesan et al. (2017) summarized the use of sintered flyash aggregate to produce structural lightweight concrete. Sintered flyash aggregate concretes have the 28-day compressive strengths in the range of 27–74 MPa, with densities in the range of 1651–2017 kg/m^3 .They reviewed that the durability properties of the flyash aggregate concretes indicate that the performance is satisfactory for structural applications.

Manu S. Nadesan et al. (2018) investigated the possibility of making high performance structural lightweight aggregate concrete using sintered flyash aggregate. In this study, identified the influence of silica fume and metakaolin on the performance of the lightweight aggregate concrete. The results demonstrate that the improvements in mechanical properties are marginal by the inclusion of silica fume and metakaolin, whereas significant enhancement to durability was observed. The carbonation results indicates that carbonation is no longer a concern for the developed concretes. It was also noticed that the mechanical and durability properties enhanced with age of curing.

III. MATERIALS

1. Cement
Portland pozzolana cement (PPC) is used for all concrete mixes. The cement used was fresh and without any slumps.

2. Coarse Aggregate
The sintered flyash lightweight aggregate is made from the sintering process of flyash as per IS: 9142 PART 2

3. Fine Aggregate
The fine aggregate used for the experimental programme was manufactured sand i.e. M sand and conformed to grading zone II as per IS: 383.1970.

4. Water
Potable tap water available in the laboratory with pH value 6 to 8 and conforming to the requirements of IS: 456-2000 is used for mixing concrete and curing the specimens.

5. Surface Improvement Liner
In this study, Controlled Permeable Formwork (CPF) liner, type II was employed. The liner has two sides, one for the drain and the other side for the filter. The properties and specification of the CPF liner as stipulated by the manufacturing entity are displayed in the Table 1

Table 1 Properties of CPF liner

S.NO	Characteristics	Values
1	Thickness at 2 kPa (mm)	1.2
2	Mean pore size (µm)	<30
3	Unit weight (g/m^2)	250
4	Tear strength in longitudinal (N)	250
5	Tear strength in transverse (N)	250
6	Air permeability at 800 Pa (l/s/m$^{2)}$	250
7	Composition	100% polypropylene

IV. MIX DESIGN

A mix design was carried out for the lightweight concrete using sintered flyash aggregate according to the procedure given by the author Manu S Nadesan et al. (2017). A grade of concrete M20 & M30 was adopted and the mix ratio are given below:

Grade of concrete	Cement	Fine aggregate	Coarse aggregate	w/c ratio
M20	1	2.71	3.32	0.75
M30	1	2.32	2.83	0.65

V. COMPRESSIVE STRENGTH

Cube specimens of size 100mm were cast to study the effect of liner on the strength of concrete. The test was carried out in compression testing machine in which the following results are obtained. The average compressive strength for the grade M20 & M30 of lightweight concrete and by using surface improvement liner are shown in the Table

Table 2 Compressive Strength test on lightweight concrete (M20)

Days	Average Compressive Strength (N/mm²)
7	20.60
14	26
28	32.21

Table 3 Compressive Strength test on lightweight concrete using liner (M20)

Days	Average Compressive Strength (N/mm²)
7	28.45
14	37.61
28	40.55

Table 4 Compressive Strength test on lightweight concrete (M30)

Days	Average Compressive Strength (N/mm²)
7	28.61
14	35.48
28	39.40

Table 5 Compressive Strength test on lightweight concrete using liner (M30)

Days	Average Compressive Strength (N/mm²)
7	35.65
14	42.51
28	47.91

Fig 1 Mould preparation to cast cube specimens

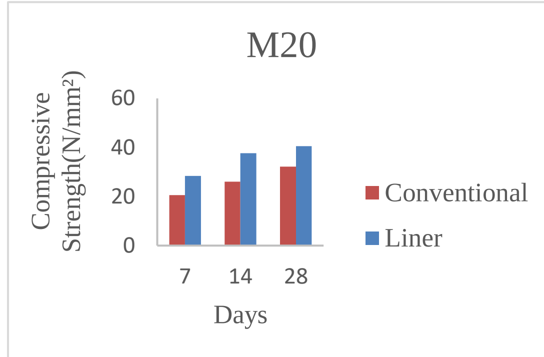

Fig 2 Comparison of compressive strength of conventional and lined concrete (M20)

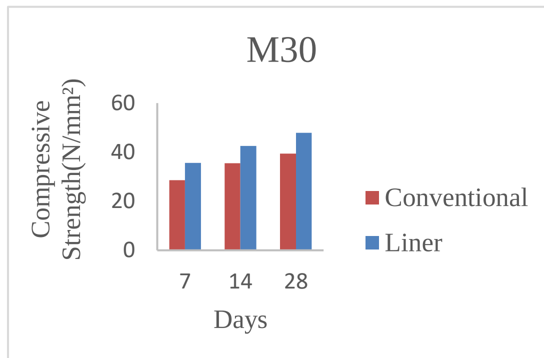

Fig 3 Comparison of compressive strength of conventional and lined concrete (M30)

VI. SPLIT TENSILE STRENGTH

Cylindrical specimen of 75mm diameter and 150mm height were casted. The average split tensile strength for the grade of concrete M20 & M30 of lightweight concrete and by using surface improvement line are shown in the Table

Table 6 Tensile Strength test on lightweight concrete

Grade of Concrete	Average split tensile strength (N/mm²)
M20	2.91
M20(Liner)	3.51
M30	3.63
M30(Liner)	4.16

VII. FLEXURAL BEHAVIOUR OF RCC BEAM

The flexural behavior of concrete was determined according to Indian Standard 516:1959. Reinforced concrete beams of length 700mm, with a cross section of 150mmx150mm were casted. Reinforced concrete beam consists of 2 numbers of 12mm diameter bars were provided in the tension zone and the stirrups of diameter 8mm@100mm c/c were provided. The beams were cured for 28 days. The load is applied until the specimen fails and the maximum load applied to the specimen during the test is recorded. The flexural behavior of conventional lightweight concrete and the lightweight concrete by using liner were compared for the grade of concrete M20 & M30.

Fig 4 Reinforcement of lightweight concrete

Fig 5 Reinforcement of lightweight concrete using liner

Fig 6 Test Setup

VIII. VALIDATION OF BEAM RESULTS

Grade of concrete: M20

Specimen No	Lightweight concrete		Lightweight concrete using liner	
	First crack (KN)	Ultimate load (KN)	First crack (KN)	Ultimate load (KN)
1	34	56.4	36	66.7
2	32	60.1	44	70.2
3	37	62.5	40	68.9

Grade of concrete: M30

Specimen No	Lightweight concrete		Lightweight concrete using liner	
	First crack (KN)	Ultimate load (KN)	First crack (KN)	Ultimate load (KN)
1	37	68.6	45	83.9
2	44	71.3	49	87.4
3	46	75.7	46	85.6

IX. RESULTS AND DISCUSSION

The compressive strength of lightweight concrete using surface improvement liner shows good results compared to the conventional lightweight concrete for both the grades M20 & M30.

The ultimate load taken by the lightweight concrete using liner were higher as compared to the conventional lightweight concrete.

The load- deflection curves for the grade M20 & M30 are given below.

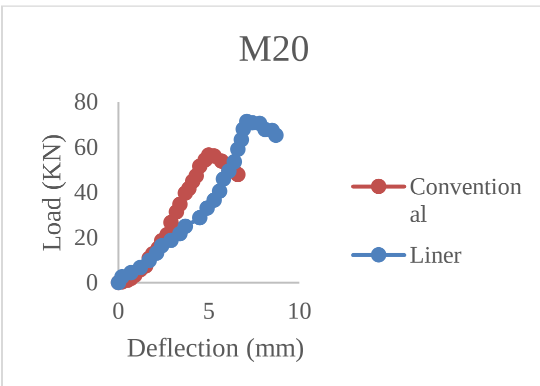

Fig 7 Comparison of flexural behavior of lightweight concrete and using liner (M20)

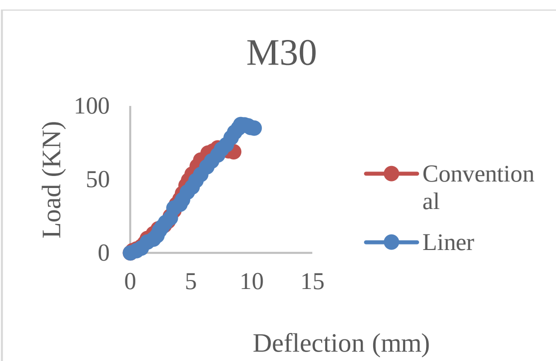

Fig 7 Comparison of flexural behavior of lightweight concrete and using liner (M20)

X CONCLUSION

Following conclusions are drawn based on the study and the results obtained in the experimental programme

- By using surface improvement liner the concrete specimens exhibited smooth and even surfaces with almost free of pin and blowholes compared to the conventional lightweight concrete.
- The effect of liner results in reduction in w/c ratio, removal of entrapped air and enrichment of cement content, produces a very dense with less porous surface zone concrete.
- It is observed that the porosity, especially near the surface is remarkably reduced by using liner, which means that the water dissipation through the liner made the surface of concrete with very fine microstructure.
- The results showed that the compressive strength and split tensile strength of lightweight concrete using liner increases as compared to the conventional lightweight concrete.
- Average ultimate load taken by the lightweight concrete beams using liner were higher when compared to the conventional lightweight concrete.
- The available limited research findings confirm that by using CPF liner the performance of concrete, in particular the durability of concrete could be enhanced substantially.

XI. 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-w.

[3] Sahil Garg, Kameshwar Singh Nim, Kunwar K. Bajpai, Sudhir Misra, Enhancement in the quality of near surface concrete using some formwork liners, Construction and Building Materials 207 (2019) 722–733.

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

119756.

[5] S. Kothandaraman,S. Kandasamy, The effect of controlled permeable formwork (CPF) liner on the surface quality of concretes, Cement and Concrete Composites (2016).

[6] S. Kothandaraman, S. Kandasamy, The effect of controlled permeable formwork liner on the mechanical properties of concrete, Materials and Structures (2016).

[7] S. Kothandaraman , S. Kandasamy, K. Sivaraman, The effect of controlled permeable formwork liner on the mechanical and durability properties of self- compacting concrete, Construction and Building Materials 118 (2016) 319–326.

[8] Wael A. Megid and Kamal H. Khayat, Effect of concrete rheological properties on quality of formed surfaces cast with self-consololidating concete and superworkable concerete, Cement and Concrete Composites (2018).

[9] Wael A. Megid, Kamal H. Khayat, Variations in surface quality of self-consolidation and highly workable concretes with formwork material, Construction and Building Materials 238 (2020) 117638.

[10] Jiaping Liu, Changwen Miao, Cuicui Chen, Jianzhong Liu, Gong Cui, Effect and mechanism of controlled permeable formwork on concrete water adsorption, Construction and Building Materials 39 (2013) 129-133.

[11] Helena Figueiras, Sandra Nunes, Joana Sousa Coutinho , Joaquim Figueiras, Combined effect of two sustainable technologies: Self-compacting concrete (SCC) and controlled permeability formwork (CPF), Construction and Building Materials 23 (2009) 2518–2526.

[12] P.J. Schubel , N.A. Warrior, K.S. Elliott, Evaluation of concrete mixes and mineral additions when used with controlled permeable formwork (CPF), Construction and Building Materials 22 (2008) 1536–1542.

[13] J. Sousa Coutinho, The combined benefits of CPF and RHA in improving the durability of concrete structures, Cement & Concrete Composites 25 (2003) 51-59.

[14] S.K. Patel, R.K. Majhi, H.P. Satpathy, A.N. Nayak, Durability and microstructural properties of lightweight concrete manufactured with fly ash cenosphere and sintered fly ash aggregate, Construction and Building Materials 226 (2019) 579–590.

[15] Manu S Nadesan, P Dinakar, Mix design and Properties of fly ash waste light weight aggregates in structural light weight concrete, Case Studies in Construction Materials (2017) https://doi.org/10.1016/j.cscm.2017.09.005.

[16] Manu S. Nadesan, P. Dinakar, Structural concrete using sintered flyash lightweight aggregate: A review, Construction and Building Materials 154 (2017) 928–944.

[17] Manu S. Nadesan, P. Dinakar, Influence of type of binder on high-performance sintered fly ash lightweight aggregate concrete, / Construction and Building Materials 176 (2018) 665–675.

[18] IS: 383, Specification for coarse and fine aggregate from natural sources for concrete 1970 Bureau of Indian Standards New Delhi 1970.

[19] IS: 456, Plain and reinforced concrete 2000 Code of Practice Bureau of Indian Standards, New Delhi 2000.