Effect of Controlled Permeable Formwork in Concrete Using Woven and Non-Woven Fabric as CPF Liner

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Abstract: ***Surface quality of the concrete is important for the durability of reinforced concrete structure, because the cover stands at the forefront defending both mechanical damages and chemical deterioration. Controlled permeable formwork (CPF) liner was developed primarily to improve the surface quality of concrete and thereby its durability. CPF liner drains mix water and entrapped air from the near surface of concrete while retaining cement and other fine particles. This helps to reduce water-cement ratio, increase cement content and decrease surface pores in the surface zone of concrete. This paper reports an experimental study carried out to study the effect of CPF liner on the strength and certain mechanical properties of concrete with three different grades of concrete. M20 & M40 was chosen for the present study. The specimens were prepared against CPF liner and impermeable steel formwork (IMF) and tested at 28 days. Various tests such as compressive, split tensile strength, rebound hammer and ultra-sonic pulse velocity tests were conducted on the normal and CPF lined concrete. The results indicate that CPF concrete performed better than IMF concrete in all aspects. From the test results, the use of CPF liner in different grade of concrete (M20&M40) improved the mechanical properties due to the formation of strong and dense Cover-Crete.***

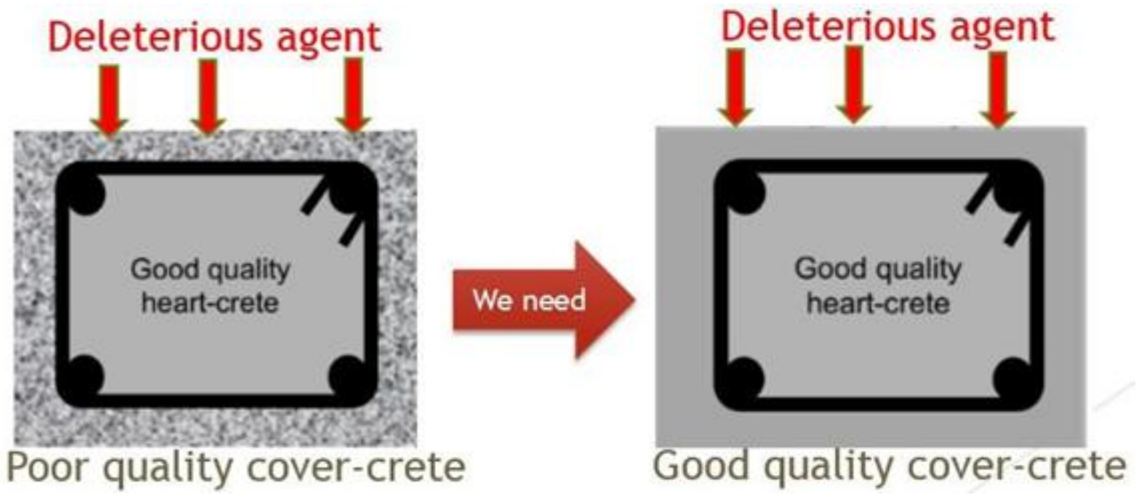
Keywords: Controlled permeable formwork, Concrete, Properties

1. Introduction

General

The quality of cover zone has a major influence on the durability of reinforced concrete elements. Cover zone forms the first line of defence against either physical or chemical deterioration. Aggressive agents penetrate into concrete through surface zone, thus the transport properties of this zone will determine the rate of penetration into the core concrete and hence its lifespan.

On the contrary, the surface of the concrete is more vulnerable to poor curing and compaction than the concrete in the heart of the section .therefore, a well compacted, dense, hard & strong concrete surface zone with low permeability and low diffusivity are preferable for durable concrete.



Showing Poor and Good quality of cover concrete

2. Existing Problems

The commonly used formworks are made from plywood or steel are essentially impermeable to air & water. When the fresh concrete is subjected to compaction by internal needle vibrator, the air and water migrate to the interface of concrete and formwork, which normally get trapped at the formwork interface. The water which reaches the interfaces the effective water- cement ratio in the cover region. Visually, this may be evident on all concrete surfaces through the presence of blowholes and pin holes following formwork removal. This is really serious problem because the first line of defence of all structural elements against carbonation, chlorides frost and abrasion, is the cover zone, which incidentally poor in quality compared to core concrete. This situation is analogous to concrete-aggregate interface. The w-c ratio around the aggregates will generally be higher compared to the remaining part of concrete.

Controlled Permeable Formwork (CPF)

Controlled permeable formwork allows air bubbles and water to drain out from the concrete surface while the cement and fine particles retained. This ensures the reduction of w-c ratio and increase in cement content in the surface zone of concrete. CPF liner creates a uniform surface, denser and less porous concrete surface. CPF liner are the formwork system essentially intended to improve the quality of the surface zone of concrete. A Schematic representation of controlled permeable formwork.

Aim and Scope of the Project

In this study, the effectiveness of CPF liner in the different grades of concrete (M20) is studied. Properties of the concrete with and without CPF will be determined by using compressive strength and split tensile strength test.

Surface hardness and quality of different grades of concrete are determined by using rebound hammer and ultrasonic velocity methods for the concrete with and without CPF liners.

3. Literature Review

Literature Review Papers

Kothandaraman and Kandasamy investigated effect of compressive strength on both controlled permeable formwork and impermeable steel formwork in 2016 and they have found that the controlled permeable formwork specimens consistently yielded higher compressive strength i.e. (2% to 5%) more than that of the conventional concrete.

McKenna has studied the effect of controlled permeable formwork liner on carbonation-induced corrosion by subjecting the concrete specimens to accelerated co_2 exposure in the year 2010. He had noticed that the controlled permeable formwork lined concrete specimens could deliver superior carbonation-induced corrosion resistance comparative than in the impermeable steel formwork.

McCarthy et al has studied on specifying concrete for chloride environments using controlled permeability formwork. He has reported in 2001 from their study that the use of controlled permeable formwork had significantly enhanced the chloride and corrosion resistance of concrete.

McCarthy and Giannakou A, in 2002 had researched on in-situ performance of controlled permeable formwork concrete in a coastal environment, and they had confirmed this performance of controlled permeable formwork lined in situ concrete under splash zone and inter-tidal regions in marine environment.

Nolan E, has investigated on effects of three durability enhancing products on some physical properties of near surface concrete, in 1995. He has confirmed that use of controlled permeable formwork liner had dramatically reduced water permeability and increased resistance to ingress of chloride and carbonation attack.

W. F. Price had investigated in 1991 on the effect of permeable formwork on the surface properties of concrete. Based on his investigation the use of permeable formwork reduces surface absorption, water permeability and chloride diffusion, while increasing surface hardness. They had observed the results show. A reduced carbonation depth for concrete cast in permeable formwork.

F.L. Serafini, had investigated on corrosion protection of concrete using a controlled permeability formwork system in 1994. He has confirmed on the more significant benefits for curing and improving the surface appearance of concrete and for creating a surface suitable to receive coating.

A. Adam, had studied on recent development in controlled permeability formwork. This shows the controlled permeable formwork is one of the recent developments to improve the durability of concrete by reducing the water cement ratio in the surface zone of the concrete.

4. Materials and Test Methods

Materials

The following sections discuss constituent materials is used for manufacturing of concrete specimens of different grades. Physical and chemical properties of the constituent materials are presented in this section.

Cement

Ordinary Portland Cement 53 grade was used to corresponding IS 12269 (1987). The chemical properties of the cement as obtained by the manufacturer are presented in the Table 3.1. Specific gravity of cement was to be found 3.12. The physical properties of the cement are shown Table 3.2.

Chemical Composition	Percentage (%)
% Silica(SiO_2)	19.79
% Alumina(Al_2O_3)	5.67
% Iron Oxide(Fe_2O_3)	4.68
% Lime(CaO)	61.81
% Magnesia(MgO)	0.84

Chemical Composition of Cement

Physical Properties	Test Results
Specific gravity	3.15
Normal consistency	32
Initial setting time (min)	50
Final setting time (min)	450
Soundness (mm)	1.2
Compressive strength (MPa) 28 days	57

Physical Properties of cement

Coarse aggregate

Crushed granite stones of size 20 mm and 10 mm are used as coarse aggregate (IS 383:2016). The physical properties of coarse aggregate are shown in Table 3.3.

Property	Test results	Values as per IS:383-2016
Specific gravity	2.7	2.1-3.2
Water absorption	0.3%	<5%

Physical properties of coarse aggregate

Fine aggregate

In this study used River sand confirming to zone II fine aggregate. The physical properties of fine aggregate are shown in Table 3.4.

Property	Test results	Values as per IS:383-2016
Specific gravity	2.5	2.5-3
Water absorption	1%	<5%
Fineness modulus	7.062	5 to 8

Physical properties of fine aggregate

Water

Generally, water that is suitable for drinking is sufficient for use in concrete. The range pH value of construction water between 6.5 to 8.5 gives the durability of structure, by decreases the corrosion of steel.

CPF

CPF (Controlled permeable formwork) liners are typically constructed of 100% polypropylene fibers, spun and thermally bonded, with a woven texture of 0.7 mm thickness. The mould without and with CPF liners of oven and non- woven fabric.

Test Methods

This section describes the test methods that are used for testing specimens of CPF and without CPF.

Slump test

Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at site of work.

The Slump Cone apparatus for conducting the slump test essentially consists of a metallic mould in the form of a frustum of a cone having the internal dimensions as: Bottom diameter: 20 cm, Top diameter: 10 cm, Height: 30 cm.

Procedure as per IS 1199:1959 Methods of Sampling and Analysis of Concrete. (Reaffirmed- Dec 2013):

The internal surface of the mould has been thoroughly cleaned and freed from superfluous moisture and any set concrete before commencing the test. The mould was placed on a smooth, horizontal, rigid and non-absorbent surface. The mould filled in four layers, each approximately one-quarter of the height of the mould. Each layer was tamped with twenty-five strokes of the rounded end of the tamping rod. The strokes distributed in a uniform manner over the cross- section of the mould and for the second and subsequent layers shall penetrate into the underlying layer.

Compressive strength test

Compressive strength test was conducted on the cubical specimens for all the mixes after 28 days of curing as per IS 516 (1991). Three cubical specimens of size 150 mm x 150 mm were cast and tested for each age and each mix. The compressive strength ($f'c$) of concrete can be calculated by ratio of the maximum load applied to the specimen to the cross-sectional area of the specimen. The mixing, tamping and casting of cylinders.

Rebound Hammer test

Rebound hammer test has been conducted on cubes as per IS-13311 (Part 2):1992 (Reaffirmed- May 2013). For taking a measurement, the rebound hammer has been held at right angles to the surface of the concrete member. The test can thus be conducted horizontally on vertical surfaces of the cube. Rebound hammer test is conducted around all the points of observation on all accessible faces of specimen.

Ultrasonic pulse velocity test

An ultrasonic pulse velocity (UPV) test is an in-situ, non-destructive test to check the quality of concrete and natural rocks. In this test, the strength and quality of concrete or rock is assessed by measuring the velocity of an ultrasonic pulse passing through a concrete structure or natural rock formation.

This test is conducted by passing a pulse of ultrasonic through concrete to be tested and measuring the time taken by pulse to get through the structure. Higher velocities indicate good quality and continuity of the material, while slower velocities may indicate concrete with many cracks or voids. By placing the transducers on opposite sides of the material.

Ultrasonic testing equipment includes a pulse generation circuit, consisting of electronic circuit for generating pulses and a transducer for transforming electronic pulse into mechanical pulse having an oscillation frequency in range of 40 kHz to 50 kHz, and a pulse reception circuit that receives the signal. A procedure for ultrasonic testing is outlined in ASTM C597 - 09. In India, ultrasonic testing is conducted according to IS 13311-1992. This test indicates the quality of workmanship and to find the cracks and defects in concrete.

5. Experimental Study

This chapter describes the experimental work. Mix design of different grades of concrete i.e. (M20).

Mix Design

Mix design for different grades (M20) re performed. Mix design of M20 was mentioned below.

Target mean strength

f'ck = fck+1.65 S
From IS 10262:2019 table no: 02, S=4
= 20 + 1.65 x 4
=26.6 N/mm^2

Selection of water cement ratio

From IS 456:2000 table no: 5, the maximum free water cement ratio for moderate exposure condition the,

W/C =0.5

Selection of water content

From IS 10262:2019 table no: 04, the maximum water content for 20mm aggregate of 50mm slump = 186 liters= 186 kg

Calculation of water cement content

W/C = 0.6

$$\Rightarrow \frac{186}{C} = 0.6$$

C = 310 kg

The minimum cement content (C) = 300 kg

Volume of coarse aggregate

The volume of coarse aggregate corresponding to 20mm size aggregate and fine aggregate of zone-2 for W/C ratio

Volume of coarse aggregate = 0.62

Volume of fine aggregate = 1-0.62

=0.38

Mix calculations

a) volume of concrete =1m^3

b) Volume of cement = $\frac{310}{3.15} \times \frac{1}{1000}$

= 0.0984 m^3

c) Volume of water = $\frac{186}{1} \times \frac{1}{1000}$

=0.186 m^3

d) Volume of all in aggregate =1-(0.0984 + 0.186)

= 0.715 m^3

e) Mass of coarse aggregate = 0.715 x 0.62 x 2.7 x 1000

=1196.91 kg

f) Weight of fine aggregate = 0.715 x 0.38 x 2.5 x 1000

=733.59 kg

Mix proportions for M20 grade

310: 733.59: 1196.91

6. Results and Discussion

Visual Inspection

As soon as the specimens were demoulded, the surface characteristics were visually scrutinised and compared. The surface morphology picture has been shown in Figure NC (normal concrete) specimens had a number of pin and blowholes on the surface. In contrast, CPF specimens exhibited even surface with almost free of pin and blowholes.

Workability

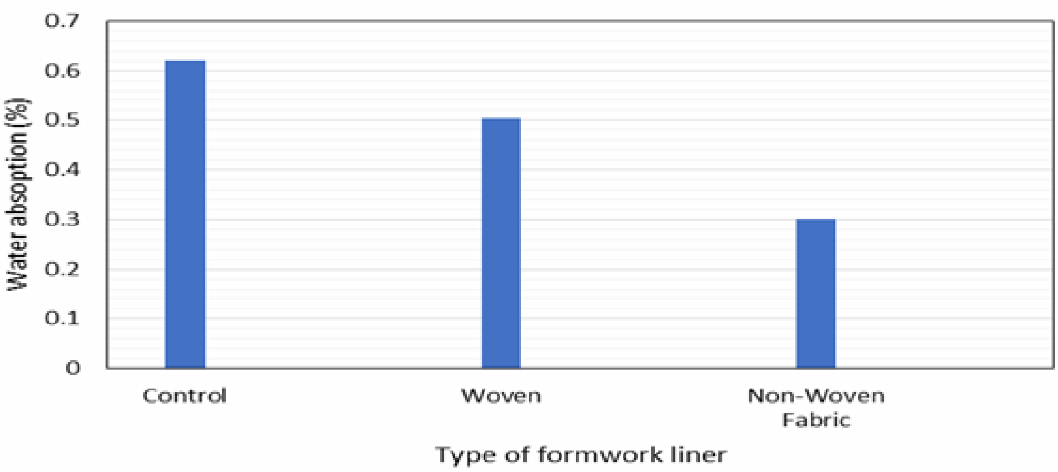
The slump of the different grades of concretes was maintained in the range of 50 to 60 mm conforming to medium workability.

Water absorption

This section describes the water absorption of concrete specimens of controlled permeable formwork and impermeable steel formwork. The water absorption values are tabulated in table below.

Cube Numbering	Weight of Cube after Taken Out from Curing (KG)	Weight of Cube after Dry (KG)	Change in Weight (KG)
1	8.23	8.21	0.02
2	8.37	8.31	0.06
3	8.32	8.29	0.03
4	7.85	7.81	0.04
5	7.33	7.29	0.04
6	8.12	8.07	0.05

Water absorption of concrete specimens



Water absorption of concrete

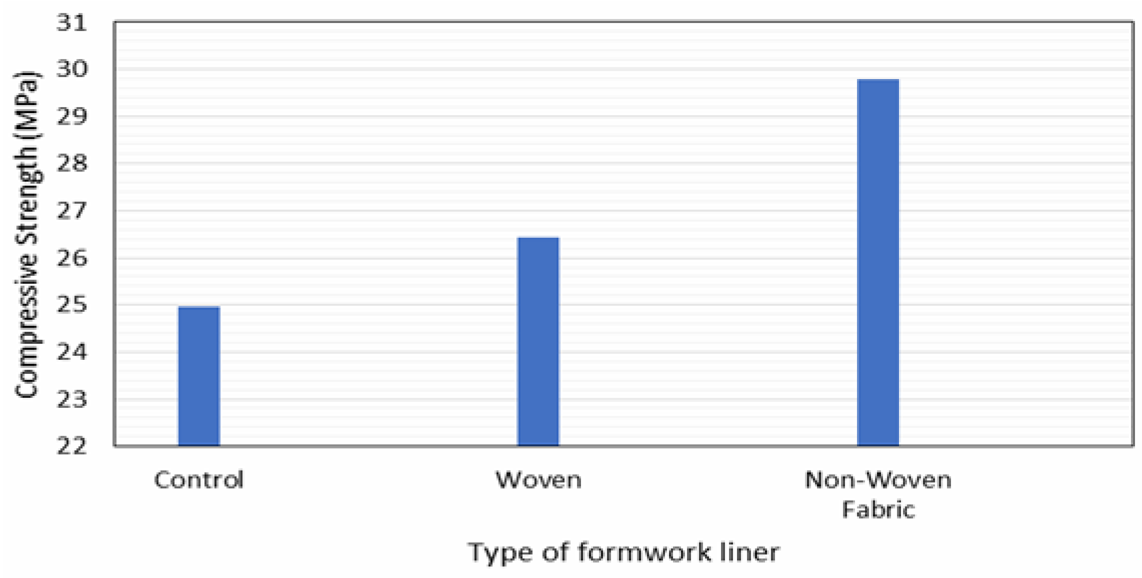
It shows the comparison of compressive strength of concrete it is observed that the variation between them is in the range of 3% to 6%. The water absorption test reflects the amount of water had been obsorved for permeable and impermeable layers.

Compressive strength

This section describes the compressive strength of concrete specimens of controlled permeable formwork and impermeable steel formwork. The compressive strength values are tabulated in table below.

Cube Numb Ering	Type of Liner	Load (KN)	C/S Area (MM.Sq)	Compressive Strength (Mpa)- 28 days =Load*1000/cross sectional area
1	Normal	500	22500	22.22
2	Normal	623	22500	27.68
3	Woven Fabric	514	22500	22.84
4	Woven Fabric	676	22500	30.04
5	Non Woven Fabric	685	22500	30.44
6	Non Woven Fabric	657	22500	29.11

Compressive strength of concrete specimens



Compressive strength of concrete

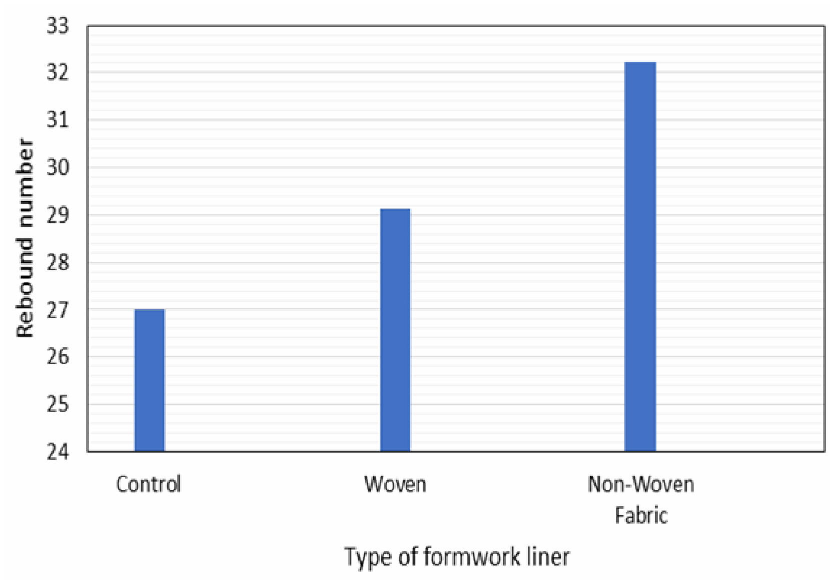
It shows the comparison of compressive strength of concrete It is observed that the variation between them is in the range of 4% to 10%. The compressive strength reflects the characteristics of the entire volume of the concrete specimen. By improving the quality of concrete at the surface level the physical behaviour of the entire mass cannot be modified.

4.3.5 Rebound Hammer test

This section describes the rebound hammer test result of concrete specimens of controlled permeable formwork and impermeable steel formwork. These values are tabulated in Table 4.4.

Cube Numbering	Type of Liner	Average Rebound Number	Compressive Strength (through graph)(Mpa)
1	Normal	29.54	23
2	Normal	30.99	24
3	Woven Fabric	29.77	24
4	Woven Fabric	29.77	24
5	Non Woven Fabric	29.55	23
6	Non Woven Fabric	31.44	25

Rebound hammer test results of concrete specimens



Rebound hammer number values of concrete specimens

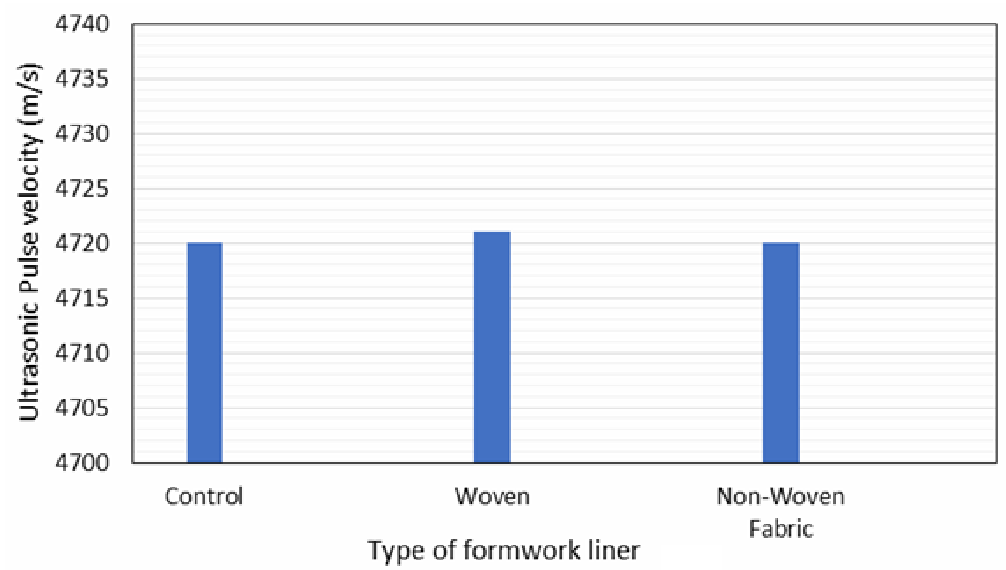
The comparison of Rebound hammer number values of concrete is shown in Figure. It is observed the variation is in the range of 10% to15%. The dense and hard surface zone formed due to controlled permeable formwork liner helps to increase rebound number.

Ultrasonic pulse velocity

This section describes the ultrasonic pulse velocity test results of concrete specimens of controlled permeable formwork and impermeable steel formwork. These values are tabulated in Table 4.5.

Material	Pulse velocity (m/s)-28 days
Normal	4777
Normal	4630
Woven Fabric	4688
Woven Fabric	4658
Non Woven Fabric	4673
Non Woven Fabric	4673

Ultrasonic pulse velocity test results of concrete specimens



Ultrasonic pulse velocity values

The comparison of Ultrasonic pulse velocity values of concrete is shown in Figure. It is observed that the variation is in the range of 1% to 2%. The controlled permeable formwork liner enhanced only the properties of surface layer. Hence not much variation was noted.

7. Conclusions and Future Scope

This chapter summarizes the overall conclusions drawn from the effect of controlled permeable formwork (CPF liner) and impermeable steel formwork (NC).

8. Conclusions

Based on the test results, the following conclusions are drawn:

By the visual inspection of concrete surface, the use of CPF liner substantially improved the surface quality of concrete, such as surface pores and airvoids.
The improvement achieved on the surface quality had ensured to assess the cube compressive strength of concrete more precisely. The existing method of assessment underestimates the cube strength of concrete by about 4% to 10%.

- The use of CPF liner had improved the surface hardness (rebound number) significantly. The improvement level was in the range of 10% to 15%.
- The improvement in the pulse velocity of CPF specimen was in the range of 1% to 2% as it deals with the uniformity of concrete.
- Overall, the use of CPF liner in different grade of concrete (M20) improved the mechanical properties due to the formation of strong and dense cover-crete.

References

[1] IS: 383 (1987) Specification for coarse and fine aggregates from natural source for concrete. Bureau of Indian Standards, New Delhi.
[2] IS: 456 (2000) Plain and reinforced concrete, code of practice. Bureau of
[3] Indian Standard, New Delhi.
[4] IS: 516 (1959) Methods of tests for strength of concrete. Bureau of Indian Standards, New Delhi.
[5] IS: 5816 (1999) Method of test for splitting tensile strength of concrete. Bureau of Indian Standards, New Delhi.
[6] IS: 13311: Part 2 (1992) Methods of test for non-destructive testing of concrete, Bureau of Indian Standards, New Delhi.
[7] IS: 10262 (2019) concrete mix proportioning-Guidelines. Bureau of Indian Standards, New Delhi.
[8] C.Chen, J. Liu, G. Cui, J. Liu, Effect of controlled permeable formwork on the improvement of concrete performances, Procedia Engineering 27 (2012) 405 – 411.
[9] S. Garg, KS. Nim, Kunwar K. Bajpai, S. Misra, Enhancement in the quality of near surface concrete using some formwork liners, Constr. Build. Mater. 207 (2019) 722–733.
[10] P.J. Schubel, N.A. Warrior, K.S. Elliott, Evaluation of concrete mixes and mineral additions when used with controlled permeability formwork, Constr. Build. Mater. 22 (2008) 1536–1542
[11] S. Kothandaraman, S. Kandasamy, K. Sivaraman, The effect of controlled permeable formwork liner on the mechanical and durability properties of self compacting concrete, Constr. Build. Mater. 118 (2016) 319–326.
[12] McKenna p. the effect of controlled permeability formwork on carbonation-induced corrosion, 3rd FIB International congress, Scotland, 2010.
[13] McCarthy MJ, Giannakou A. In-situ performance of Controlled permeable formwork concrete in a coastal environment, cement and concrete research 2002; 32:451-457.
[14] W.F. Price, S.J. widows, the effect of permeable formwork on the surface properties of concrete, Mag. Concr. Res. 43 (1991) 93-104.
[15] P. McKenna, Effect of Controlled permeability formwork on concrete structures in marine environment, FIB Symposium on concrete structures-Stimulators of Development, Dubrovnik, Croatia, 2007, pp.20- 23.
[16] A.A. Adam, D.W. Law, T. Molyneaux, I. Patnaikuni, T. Aly, The effect of using controlled permeability formwork on the durability of concrete containing OPC and PFA, Aust. J. Civ. Eng. 6 (2010) 1-12.
[17] P.A.M. Basheer, A.A. Sha'at, A.E. Long, F.R. Montgomery, Influence of controlled permeability formwork on the durability of concrete, Proceedings of the International Conference, Concrete 2000, Economic and Durable Construction through Excellence, Vol.1, E & F N Spon, London, 1993, pp. 737-748