THE EFFECT OF PERMEABLE FORMWORK (CPF LINER) ON STRENGTH AND DURABILITY PROPERTIES OF M30 & M35 GRADE CONCRETE

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ABSTRACT

The longevity of any reinforced concrete element is determined by the quality of the cover concrete. The only way for aggressive chemicals to get into the structural components and cause rebar corrosion and other types of damage is through the cover concrete. The controlled permeable formwork (CPF) liner is a unique approach for enhancing the quality of cover concrete. This liner permits surplus water and trapped air to escape while keeping the cement and fine particles in place on the concrete surface. Due to the modification, the water-cement (w/c) ratio is reduced, cement content is increased and surface porosity in the concrete cover zone is reduced. The influence of CPF liner on strength and durability property was investigated in this study. Concrete samples were cast against a CPF liner and impermeable formwork (IMF) at different grades. The compression strength test, tensile strength test, flexural strength test and durability tests is all examined at various ages. The results expected that CPF concretes exhibited good quality and appearance to the structure.

The strength and durability performance of CPF lined concrete is expected to be increased from the study as compared to conventional type formwork concrete (IMF).

INTRODUCTION

1.1 GENERAL

The leftover mix water and entrapped air on a concrete surface degrades the appearance of concrete structures and reduces their durability. The quality of the cover concrete determines the durability of reinforced concrete elements. Aggressive agents from the surrounding environment, such as chlorides and carbon dioxide, will infiltrate the reinforced concrete through the cover concrete, causing rebar corrosion and other types of damage. The quality of the cover concrete was not given the same consideration. As a result, many structures have begun to exhibit indications of degradation sooner than planned for their service life, resulting in significant costs for repair and rehabilitation. Nowadays, the prescriptive method defines limitation values for specific material qualities (w/c ratio, cement type, cover and so on) based on various environmental circumstances and the concrete structure's projected service life, without effectively addressing the issue of concrete cover quality. The bulk characteristics of concrete may impact such limiting values. Due to a build-up of surplus water (H2O) and entrapped air at the interface of concrete-formwork, the cover concrete is porous and permeable

The commonly used formwork, made from the impregnated plywood, steel or plastic, are essentially impermeable to air and water. It has been mentioned by a number of researchers that due to vibration caused by concrete compaction and hydrostatic pressure, water and air migrate towards the formwork. Therefore, the effective water/cement (w/c) ratio increases in the cover region. Further, the trapped air bubbles create pinholes, accumulated water creates blow holes and other forms of blemishes on the concrete surface. As a result of this the covercrete will be of poorer quality compared to heartcrete [2].

The utilisation of a CPF (controlled permeable formwork) liner is a unique approach for enhancing the quality of cover concrete [1]. This method employs a non- woven polypropylene fibre fabric liner affixed to conventional formwork, as seen in Fig. 1.1. The CPF liner permits surplus water and trapped air to escape while keeping the cement and fine particles in place on the concrete surface. This lowers the w/c fraction, raises the cement constituent and lowers surface porosity in the concrete cover zone. The cover concrete becomes denser, stronger, and less porous. This modification increased the splitting and flexural strength, abrasion resistance, transport and diffusion properties of concrete significantly. The thickness of the concrete cover increased owing to CPF liner was 5–30 mm, in addition to the strength and durability features.

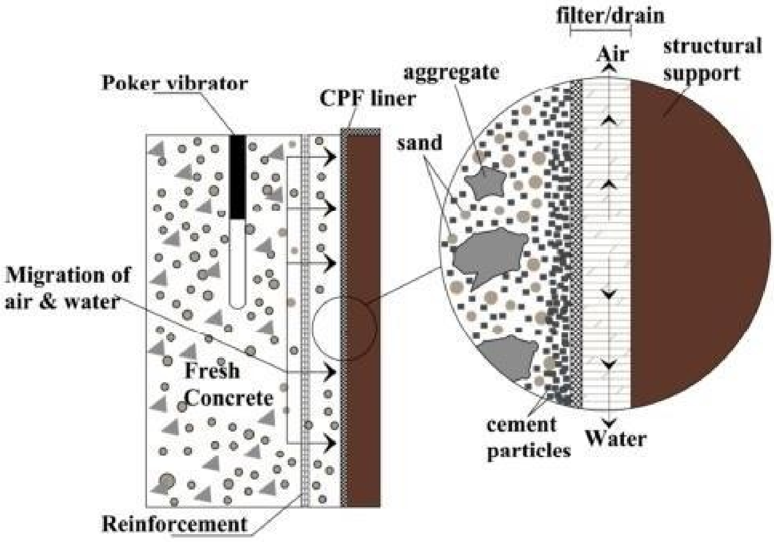


Fig1.1:Schematic representation of controlled permeable form work (CPF)

1.2 ADVANTAGES

- Improve the quality of cover concrete
- Water cement ratio is reduced
- Surface porosity reduced
- Liner can be reused (based on the work done)
- Self - adhesive

1.3 DISADVANTAGES

- Not readily available
- Imported material

1.4 OBJECTIVES

☐ To study the effectiveness of CPF liner in M30 & M35 concrete.

☐ To study the strength and durability properties of concrete with and without CPF liner.

☐ To compare the effectiveness of CPF liner in both M30 & M35 concrete.

1.5 SCOPE OF THE STUDY

The main scope of this study is to evaluate effectiveness of CPF liner in the M30 grade concrete and M35 grade concrete. Properties of the concrete with and without CPF will be determined by using compressive strength test, split tensile strength test, flexural strength tests and durability tests.

1.6 SCHEME OF WORK

☐ Conducting literature survey
☐ Fixing objectives
☐ Material testing
☐ Design Mix preparation
☐ Casting required samples
☐ Testing each samples
☐ Result interpretation

LITERATURE REVIEW

2.1 STUDIES ON PREVIOUS LITERATURES

Selvaraj Kandasamy, S. Kothandaraman (2004) The experimental investigation was proposed to study the effect of CPF liner on the surface hardness and wear of concretes. Suitable size specimens were cast against CPF liner and (impermeable) steel formwork (IMF) and tested at various ages. Three mixtures of conventional concrete (CC) and one SCC were considered in this work. They were designated as CC33, CC40, CC45 and SC43 respectively. The tests were made on 100mm size cubes at the ages of 7, 28, 90 and 365 days. The test conducted were Rebound number, Dynamic hardness number, Rockwell superficial hardness number, Wear resistance, Abrasion resistance etc.. The results revealed that the surface quality/hardness of CPF concretes enhancedby 14% - 58%. Further, 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 changein the quality of cover concrete was found to be consistent over the w/c ratio of 0.31 to 0.48.

Philip McKenna, Chirag Baxi (2008) In this investigation shall compare concrete cast against conventional Impermeable Formwork (IMF) and demonstrate how a Controlled Permeability Formwork (CPF) liner can reduce initial construction costs, whilst at the same time achieving durability, through the natural enhancement of the near surface cover. Average of 3 design strengths (C20/25, C30/37 and C35/45 N/mm2), average of 5 cements types (PC, PFA, GGBS, MK & CSF), average of 4 admixtures types (WR, SP, AE and WP) were used. CPF Liners are a proven method of enhancing the cover area of structural concrete. In aggressive environments, today's designers no longer need to accept inferior or deficient concrete surfaces, nor need apply finite life protection systems. W. Lin, Q., Jiang, J. Liu (2014) In this paper, influence of the CPF on the permeability of concrete was studied with different water to binder ratio, fluidity, and fly ash content. Result shows that CPF could make the concrete surface blow- hole free with no blemishes, which prepares the ground for better permeability performance of concrete. By removing excessive water and air bubbles, CPF could make better the concrete performance such as rebound strength, especially permeability, proved by water sorption test and Coulomb electric flux test. CPF has better performance on the concrete mixture with high w/b ratio and proper fly ash content.

Cuicui Chena, Jianzhong Liu a, Gong Cui a, Jiaping Liu (2012) In this chapter, the influence of controlled permeable formworks (CPF) on concrete, samples were made in steel modulus with and without CPF. Visible surface morphology, adsorption of water and chloride, permeability of Cl- , together with pore structure of the surface layers were studied and analyzed. The application of CPF, concrete could be enhanced and the surface is homogeneous without any visible blow-holes. Also, adsorption and permeability of water and chloride ion into concrete were inhibited. Test conducted were Rebound hammer test, water adsorption test, pore structure test.

According to mercury intrusion porosimeter, the porosity in the thickness of 0-3mm under surface was reduced from 10.48% of the control sample to 7.04%. The largest decrease existed in pores with diameter of larger than 0.2 μm. The study indicates that CPF could markedly improve the appearance as well as the durability of concrete structures.

W. F. Price, BSc PhD, S. J. Widdows, BEng*(2012) In this study the surface properties of concretes cast in both conventional (impermeable) formwork and in permeable formwork have been compared. The effect of subsequent curing after stripping the formwork has also been examined. Three grades of concrete (C20, C30 and C50) have been tested. The laboratory test programme has demonstrated that the use of permeable formwork reduces surface absorption, water permeability and chloride diffusion, while increasing surface hardness. The incidence of blowholes on the formed surfaces is greatly reduced even for high–strength concrete. Results from both laboratory and site trials show a reduced carbonation depth for concrete cast in permeable formwork. A reduction in the near surface water/cement ratio can also be demonstrated. The overall conclusion drawn from this work is that the surface properties of concrete can be considerably improved by the use of permeable formwork.

A similar performance may be expected from a grade C30 concrete cast in permeable formwork relative to a grade C50 concrete cast in conventional formwork.

Vishal M Ambad, Raju Narwade, Dr. Karthik Nagarajan (2021) This paper investigates experimentally the impact of CPF liner on the concrete surface against chloride penetration. The concrete mix contained ordinary Portland cement (OPC) 53, pulverized fly ash (PFA), Micro silica, locally available aggregates, crushed sand, water and superplasticizer. The cylindrical and cubical concrete specimens were cast with impermeable steel formwork (SF) and CPF liner. The cubic and cylindrical specimens were tested at the age of 7 days and 28 days. Compressive strength and Rapid chloride penetration tests (RCPT) were conducted. The concrete cast with CPF liner gives excellent compressive strength 14% more than specimens cast with steel formwork and has acquired better resistance against Chloride penetration. The results show that the concrete sample cast with CPF liner shows 9.98% less charges passed than specimens cast with steel formwork.

E. Nolan P.A.M., Basheer A.E. Long (2013) This paper investigates the influence of three fundamentally different durability enhancing products, viz. microsilica, controlled permeability formwork and silane, on some of the physical properties of near surface concrete. Microsilica (silica fume) is a pozzolan, controlled permeability formwork (CPF) is used to provide a free draining surface to a concrete form, while silane is a surface treatment applied to hardened concrete to reduce the ingress of water. Comparisons are made between the products when used individually and used in conjunction with each other, with a view to assessing whether the use of combinations of products may be desirable to improve the durability of concrete in certain circumstances. The effect of these materials on various durability parameters, such as freeze-thaw deterioration, carbonation resistance and chloride ingress, is considered in terms of their effect on permeation properties and surface strength. The results indicated that a combination of silane and CPF produces concrete with very low air permeability and sorptivity values. The influence of microsilica was more pronounced in increasing the surface strength of concrete.

A. Balasaikumar, Dr. K Thulasirajan (2022) The current experimental work is carried out to observe the effect of CPF liner on mechanical properties of M20 grade concretes with the varying percentages (0%, 1%, and 2%) of steel fibres. The samples were created with CPF liner and impermeable steel formwork and conducted test at 28 days. Different tests like compressive strength, split tensile strength, rebound hammer and ultrasonic pulse velocity tests were done on the normal and CPF-lined concrete. From the test result the performance of CPF-lined concrete is high at various percentage of steel fibre reinforced concrete as compared to normal concrete. At last, the uses of CPF liner in the M20 grade of concrete are effective in both compression and tension with adding of steel fibres in the concrete.

Andi Adam Menaka B, Dr. Sundari, Dr. G. Arun Kumar (2020) This paper aims to present the influence of CPF liner concerning the properties such as surface hardness and durability characteristics of CPF concrete. It was reported that there is significant improvement in strength, durability and near surface concrete quality improvement in CPF liner than that of impermeable formwork (IMF) liner. The studies conducted were surface hardness of CPF concrete by Rebound number, Pull-off strength, Abrasion Resistance and Durability characteristics of CPF concrete by Water permeability, Air permeability, Water absorption, sorptivity .

2.2 SUMMARY OF LITERATURES

The longevity of any reinforced concrete element is determined by the quality of the cover concrete. The controlled permeable formwork (CPF) liner is a unique approach for enhancing the quality of cover concrete. This liner permits surplus water and trapped air to escape while keeping the cement and fine particles in place on the concrete surface. The utilization of a CPF (controlled permeable formwork) liner is a unique approach for enhancing the quality of cover concrete. This method employs a non-woven polypropylene fiber fabric liner affixed to conventional formwork [1].

2.3 RESEARCH GAP

There are no researchers conducted the study based on strength and durability performance of M30 & M35 grade concrete. In this project we are going evaluate strength and durability performance of M30 & M35 concrete with and without CPF liner.

2.4 NEED FOR THE STUDY

Controlled permeability formwork (CPF) which was originally developed to obtain much smoother surface of the concrete proves to promote the service performance of the concrete by enhancing the surface layer which could protect the structure from all kind of defects. To improve the strength durability and all other performance of the concrete, the use of CPF liner is necessary.

METHODOLOGY

3.1 MATERIALS USED

The major materials used are cement, sand, aggregate etc..

3.1.1 CEMENT

A cement is a binder, a substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand and gravel together. Cement mixed with fine aggregate produces mortar for masonry, or with sand and gravel, produces concrete. The cement used is RAMCO PPC grade 43.

Fig3.1:Cement

3.1.2 WATER

Water is an inorganic, transparent, tasteless, odorless, and nearly colorless chemical substance, which is the main constituent of Earth & hydrosphere and the fluids of all known living organisms. It is vital for all known forms of life, even though it provides no calories or organic nutrients.

3.1.3 SAND

Sand is a mixture of small grains of rock and granular materials which is mainly defined by size, being finer than gravel and coarser than silt. And ranging in size from 0.06 mm to 2 mm Particles which are larger than 0.0078125 mm but smaller than 0.0625 mm are termed silt.

Sand is made by erosion or broken pebbles and weathering of rocks, which is carried by seas or rivers. And freezing and thawing during the winter break rock up the sand will be made. Sometimes Sand on beaches can also be made by small broken-up pieces of coral, bone, and shell, which are broken up by predators and then battered by the sea, and even tiny pieces of glass from bottles discarded in the sea and other mineral materials or the bones of fishes or other oceanic animals. Sand can be also considered as a textural class of soil or soil type. A sandy soil containing morethan 85 percent sand-sized particles by mass. The sand used is M sand and is collected from the nearby shop.

Fig 3.2: Sand

3.1.4 COARSE AGGREGATE

Coarse aggregates refer to irregular and granular materials such as sand, gravel, or crushed stone, and are used for making concrete. In most cases, Coarse is naturally occurring and can be obtained by blasting quarries or crushing them by hand or crushers. Aggregate materials help to make concrete mixes more compact. They also decrease the consumption of cement and water and contribute to the mechanical strength of the concrete, making them an indispensable ingredient in the construction and maintenance of rigid structures. The maximum size of the selected coarse aggregate is 20 mm. It is collected from the nearby shop.

Fig 3.3: Coarse Aggregate

3.1.5 CONTROLLED PERMEABILITY FORMWORK (CPF LINER)

CPF liners are permeable to air and water, but prevent the escape of cement and other fine particles. 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/skin. The utilisation of a CPF (controlled permeabl formwork) liner is a unique approach for enhancing the quality of cover concrete. This method employs a non-woven polypropylene fibre fabric liner affixed to conventional formwork. In this investigation, the type II CPF liner was employed, which consist of two sides: one that acted as a filter and the other that acted as a drain. CPF liner was purchased from fibretex ltd. Banglore.

Fig 3.4: Controlled permeability formwork (CPF liner)

3.2 METHODOLOGY

Mix design is done according to the IS design method and numerous trial mixes were conducted to get optimum mix. Once the optimum mix is determined, it is used to produce concrete specimens with and without CPF liner. The concrete is prepared to find out the compressive strength, flexural strength, split tensile strength and durability tests.

3.3 TESTING OF MATERIALS

To examine the basic properties of the materials chosen the following tests were carried out.

3.3.1 TESTS ON CEMENT

Cement is the most important ingredient in concrete. Therefore quality of cement should be checked before using it. Various tests on cement are performed to evaluate the specific gravity, standard consistency and initial setting time.

3.3.1.1 Specific gravity of cement

As per IS 4031, the specific gravity is the ratio between the weight of a given volume of material and weight of an equal volume of water. The dry Le Chatelier Flask was cleaned and filled with kerosene up to the mark. 60g of cement was taken. The initial reading of flask (V1) was noted. Add 60g of cement into the flask with care. Care should be taken so that cement is falling properly into the flask. Shake the flask with stopper so that no cement is stick to walls of flask. The cement was allowed to settle. The final reading of flask (V2) was noted.

$$\text{Specificgravityofcement} = Weightofcement / Weightofkerosine$$

Fig 3.5: Le chatelier's flask

3.3.1.2 Standard Consistency of cement

As per IS 4031 & IS 269, about 400 g of cement was weighed accurately and placed in an enamel trough. To start with, add clean water and mixed it thoroughly with cement. Care should be taken that the time of gauging is not less than 3 minutes and not more than5 minutes. The gauging time shall be counted from the time of adding water to the dry cement until commencing to fill the mould. The Vicat's mould was filled with this paste. Make the surface of the cement paste in level with the top of the mould.

The mould was placed under the rod bearing the plunger. The indicator was adjusted to show 0-0 reading when it touched the surface of the test block. The plunger was released quickly, allowing it to sink into the plate. The trial paste was prepared with varying % of water and the test was repeated as described above until the needle penetrates 5mm to 7mm above the bottom of the mould. The amount of water was expressed as percentage by weight of the dry cement.

$$Standrdconsistency = Quantityofwaterfor5{-}7mmpenetration / Weightof\text{cement} \times 100$$

Fig 3.6: Vicat Apparatus

3.3.1.3 Initial Setting of cement

According to IS 4031 & IS 269, the initial setting time of concrete is the time when cement paste starts hardening while the final setting time is the time when cement paste has hardened sufficiently in such a way that a 1 mm needle makes an impression on the paste in the mould but 5 mm needle does not make any impression.

Time about 400 grams of cement was weighed. A neat cement paste was prepared by adding 0.85 times the percentage of water required for standard consistency. The stopwatch was started at the instant when water was added to the cement. The Vicat's mould was filled with the cement paste prepared. Gauging time should not be less than 3 minutes and more than 5 minutes. Filled the mould completely and smoothened the surface of paste making it level with the top of the mould to give a test block. The test block was placed confined in the mould under the load bearing medium. Lowered the needle gently till it came in contact with the surface of test block and was quickly released, allowing it to penetrate the test block and noted penetration after every twominutes. This procedure was repeated until the needle failed to pierce the block forabout 5mm, measured from the bottom of the mould. The stopwatch was stopped and the initial setting time was noted.

Fig3.7:Vicat Apparatus

3.3.2 TESTS ON FINE AGGREGATES

Fine aggregates are very important component of concrete, so its quality really matters. Various tests such as specific gravity, sieve analysis are performed on fine aggregates to check its quality. Specific gravity test of aggregates is done to measure the strength of the aggregates

3.3.2.1 Specific gravity of Fine Aggregates

As per IS 2386 (part 3) the Pycnometer was cleaned, dried and weighed accurately with its cap screwed on (W1). About 300g to 500g of oven dry sample in the Pycnometer was taken and weighed again (W2). Distilled water was added in the Pycnometer and stirred using glass rod to remove the entrapped air. Filled the Pycnometer with distilled water up to the hole in the conical cap and weighed it (W3).

The Pycnometer was emptied and cleaned. Filled the Pycnometer with distilled water up to the hole in the conical cap and weighed it (W4).

$$\text{Specific gravity} = \frac{W2}{W2-(W-W1)}$$

Fig3.8:Pycnometer

3.3.2.2 Water absorption of fine aggregates

According to IS 2386 (part 3) about 2kg of aggregate sample is taken in a wire basket and immersed in water at a temperature of 22ºC to 32ºC. Entrapped air is removed from the sample by lifting the basket 25 mm above for 25 times. The basket with sample kept completely in water for 24 hours. The basket and aggregate are weighed are weighed while suspended in water. The basket and aggregate are removed from water and dried with dry absorbent cloth. The surface dried aggregates are also weighed

$$Waterabsorption(\%) = \frac{W1-W2}{W2} \times 100$$

3.3.2.3 Sieve analysis of fine aggregates

About 1 kg of fine aggregate was taken in IS sieve size of 4.75mm, 2.36mm, 1.18mm, 600µ, 300µ, 150µ, pan were arranged in the decreasing order of size and put the coarse aggregate taken. Sieved the aggregates and the amount which is passing through greater size was taken and retained on the next. A graph with Percentage finer versus sieve size was plotted with the values obtained from the tests.

Fig 3.9:Sieve

3.3.3 TESTS ON COARSE AGGREGATES

Coarse aggregates are very important component of concrete, so its quality really matters. Various tests such as specific gravity, sieve analysis are performed on fine aggregates to check its quality. Specific gravity test of aggregates is done to measure the strength of the aggregates.

3.3.3.1 Specific gravity of coarse aggregates

About 2kg of thoroughly washed coarse aggregate was placed in the wire basket and immersed it in distilled water. The weight of the saturated aggregate suspended in water with the basket was weighed and noted as (W1). Removed the basket and aggregate from the water and allowed it to drain. Immerse the basket in water and the empty weight (W2) was taken. Oven dried the aggregates for a temperature of 110°C for 24 hours. The weight of oven dried aggregate (W3) was noted.

Specific gravity = W3 / W3 - (W1- W2)

3.3.3.2 Water absorption on coarse aggregates

According to IS 2386 (part 3) about 2kg of aggregate is taken in a wire basket and immersed in water at a temperature of 22ºC to 32ºC. Entrapped air is removed from the sample by lifting the basket 25 mm above for 25 times. The basket with sample kept completely in water for 24 hours. The basket and aggregate are weighed are weighed while suspended in water. The basket and aggregate are removed from water and dried with dry absorbent cloth. The surface dried aggregates are also weighed.

$$Water absorption(\%) = \frac{W1-W2}{W2} \times 100$$

3.3.3.3 Sieve analysis of coarse aggregates

About 1 kg of coarse aggregate taken in IS sieve size of 25mm, 20mm, 16mm, 12.5mm, 10mm, 4.75mm. The sieves were arranged in the decreasing order of size and put the aggregate taken. Sieved the aggregates and the amount which is passing through greater size was taken and retained on the next. The laboratory test on sieve analysis of coarse aggregate was conducted.

Fig 3.10: sieve

3.4 DESIGN MIX

3.4.1 MIX CALCULATION

3.4.1.1 CONCRETE MIX DESIGN- M35 GRADE

Codes used: IS 456:2000 & IS 10262: 2019

1. Stipulation for proportioning
• Grade designation =M35
• Type of cement grade =PSC
• Max. size of coarse aggregate =20mm
• Exposure condition =severe
(IS 456 -2000, Table 5, pg.20)
• Min. cement content =340 kg/m 3
• Max w/c ratio = 0.45
• Workability in terms of slump = 100mm
•Max cement content = 450kg/m^3 (IS456-2000Cl.8.2.4.2,Pg.10)
Aggregate = zone II (IS 456-10262-2019)
☐ Critical admixture type: super plastisizer

2.Test data for materials
• Specific gravity of cement = 3.05
• Specific gravity of coarse aggregate =2.81

• Specific gravity of fine aggregate=2.66 3.
Target strength for mix proportion
f'ck = fck + (1.65×s)
s =5 (IS 10262.2019-Table 2- pg.3)
fck =$35N/mm^2$
f'ck =35+ (1.65×5)
=43.25N/mm 2
4. Selection of w/c ratio
w/c ratio for target mean strength = 0.38 (Pg 4, IS 10262)
Exposure condition = Severe
w/c ratio for exposure condition = 0.45
0.38 < 0.45 Hence Ok
5. Approximate air content
For 20mm nominal max. size of aggregate,
approximate amount of entrapped air = 1% (Table 3 page 3 IS 10262)
6. Selection of water content
For 20mm max. size aggregate water content = 186 kg (Table 4, pg 5 IS 10262)
Estimated water content for 25mm slump
(Increasing at rate of 3% for every 25mm slump)
= 186 + 3 × 186
100
= 191.58 kg
As super plasticer is used water content maybe reduced to 20 – 30%
Considering water content reduction by 23%
Water content = 191.58 – 23 × 191.58
100
= 148kg
7. Calculation of cement content
w/c ratio = 0.38
cement content = Water content
w/c ratio

= 148 = 389.47 = 390kg/m 3
0.38
390kg/m 3 > 340kg/m 3

8. Propotion of Vol. of CA & FA
Proportionate vol. of CA corresponding to 20mm nominal size
of CA & FA (zone II) for w/c 0.50 = 0.62 (Table 5 pg 6 IS 10262)
Change in w/c ratio = 0.50 – 0.38
= 0.12

Corrected propotion of vol of CA for w/c ratio 0.38 = 0.62 + 0.12 × 0.01
0.05

ie; Vol. of CA content = 0.644m 3
Vol. of FA content = 1- 0.664 = 0.356m 3
9. Mix calculation
• Total volume = 1m 3
• Volume entrapped air = 1% = 0.01
• Vol of cement = mass of cement × 1
Specific gravity of cement 1000
= 390 × 1
3.05 1000
= 0.1278 m 3

• Vol of water = mass of water × 1
Spc. gr of water 1000
= 148 × 1
1 1000
= 0.148 m 3

• Vol. of chemical admixture = mass of chemical admixture × 1
(0.4% by mass of cementatious material) spc. gr of admixture 1000

= 390 × 0.4% × 1
1.04 1000
= 0.001485 m 3

• Vol. of total aggregate = [(total vol.(a) – vol of entrapped air (b)) – (vol of
Cement (c)+ vol of water (d) + vol of chemical Admixture)]
= [(1-0.01) – (0.1278 + 0.148 + 0.001485)]
= 0.713 m 3
• Mass of CA = Vol of total aggregate × vol. of CA × spc. gr. Of CA × 1000

= 0.713 × 0.644 × 2.81 × 1000
= 1290 kg

• Mass of FA = Vol. of total aggregate × Vol. of FA × Spc. gr. of FA × 1000

= 0.713 × 0.356 × 2.66 × 1000
= 675 kg

• Mass of chemical admixture = Vol. of total aggregate × Vol. of chemical
Admixture × spc. gr. of admixture × 1000

= 0.713 × 0.001485 × 1.04× 1000
= 1.10 kg

• Mix propotion for trail mix
☐ Cement = 390 kg/ m 3

☐ Water = 148 kg / m 3

☐ CA = 1290 kg/ m 3

☐ FA = 675 kg/ m 3

☐ Admixture = 1.10 kg/ m 3

☐ w/c ratio = 0.38

• Ratio of M35 mix = C : FA : CA
= 390 : 675 : 1290
390 390 390
= 1 : 1.73 : 3.31

3.4.1.2 CONCRETE MIX DESIGN- M30 GRADE

Codes used: IS 456:2000 & IS 10262: 2019

1. Stipulation for proportioning

• Grade designation =M30
• Type of cement grade =PSC
• Max. size of coarse aggregate =20mm
• Exposure condition =severe
(IS 456 -2000, Table 5, pg.20)
• Min. cement content =320 kg/m 3
• Max w/c ratio = 0.45
• Workability in terms of slump = 100mm
• Max cement content = 450kg/ m 3
(IS 456-2000 Cl.8.2.4.2, Pg.10)

☐ Aggregate = zone II (IS 456-10262-2019)

☐ Critical admixture type: super plastisizer

2. Test data for materials

• Specific gravity of cement = 3.05
• Specific gravity of coarse aggregate =2.81
• Specific gravity of fine aggregate=2.66 3.

Target strength for mix proportion
f’ck = fck+(1.65×s)
s =5 (IS 10262.2019-Table 2- pg.3)
fck =30 N/ mm^2
f’ck =30 + (1.65×5)
=38.25N/mm 2

4. Selection of w/c ratio

w/c ratio for target mean strength = 0.42 (Pg 4, IS 10262)
Exposure condition = Severe
w/c ratio for exposure condition = 0.45
0.42 < 0.45 Hence Ok

5. Approximate air content

For 20mm nominal max. size of aggregate,
approximate amount of entrapped air = 1% (Table 3 page 3 IS 10262)

6. Selection of water content

For 20mm max. size aggregate water content = 186 kg (Table 4, pg 5 IS 10262)
Estimated water content for 25mm slump
(Increasing at rate of 3% for every 25mm slump)
= 186 + 3 × 186
100
= 191.58 kg

As superplasticer is used water content maybe reduced to 20 – 30%
Considering water content reduction by 23%
Water content = 191.58 – 25 × 191.58
100
= 143kg

7. Calculation of cement content

w/c ratio = 0.42
cement content = Water content
w/c ratio
= 143 = 340Kg/m 3
0.42
340kg/m 3 > 320kg/m 3

8. Propotion of Vol. of CA & FA

Proportionate vol. of CA corresponding to 20mm nominal size
of CA & FA (zone II) for w/c 0.50 = 0.62 (Table 5 pg 6 IS 10262)
Change in w/c ratio = 0.50 – 0.42
= 0.08

Corrected propotion of vol of CA for w/c ratio 0.42 = 0.62 + 0.08 × 0.01
0.05

ie; Vol. of CA content = 0.636m 3
Vol. of FA content = 1- 0.636 = 0.364m 3

9. Mix calculation

• Total volume = 1m 3
• Volume entrapped air = 1% = 0.01
• Vol of cement = mass of cement × 1
Specific gravity of cement 1000
= 340 × 1
3.05 1000
= 0.111 m 3

• Vol of water = mass of water × 1
Spc. gr of water 1000
= 143 × 1
1 1000
= 0.143 m 3

• Vol. of chemical admixture = mass of chemical admixture × 1
(0.4% by mass of cementatious material) spc. gr of admixture 1000
= 340 × 0.4% × 1
1.04 1000
= 0.001307 m 3

• Vol. of total aggregate = [(total vol.(a) – vol of entrapped air (b)) – (vol of
Cement (c)+ vol of water (d) + vol of chemical Admixture)]
= [(1-0.01) – (0.111 + 0.143 + 0.001307)]
= 0.735 m 3

• Mass of CA = Vol of total aggregate × vol. of CA × spc. gr. Of CA × 1000

= 0.735 × 0.636 × 2.81 × 1000
= 1313.5 = 1314 kg

• Mass of FA = Vol. of total aggregate × Vol. of FA × Spc. gr. of FA × 1000

= 0.735 × 0.364 × 2.66 × 1000
= 711.6 = 712 kg

• Mass of chemical admixture = Vol. of total aggregate × Vol. of chemical
Admixture × spc. gr. of admixture × 1000

= 0.735× 0.001307 × 1.04 × 1000
= 0.9997 = 1 kg

• Mix propotion for trail mix
- Cement = 340 kg/ m 3
- Water = 143 kg / m 3
- CA = 1314 kg/ m 3
- FA = 712 kg/ m 3
- Admixture = 1 kg/ m 3
- w/c ratio = 0.42

• Ratio of M35 mix = C: FA: CA
= 340 : 712 : 1314
340 340 340
= 1 : 2.09 : 3.86

Table 3.1 Optimum mix preparation of M35 grade concrete

Materials	**Water (L)**	**Cement (kg)**	**Fine Aggregate (kg)**	**Coarse Aggregate (kg)**	**Super Platisizer (kg)**
Quantity of 1 $m^3$of concrete	148	390	675	1290	1.10
Mix Ratio	0.38	1	1.73	3.31	0.0028

Table 3.2 Optimum mix preparation of M30 grade concrete

Materials	**Water (L)**	**Cement (kg)**	**Fine Aggregate (kg)**	**Coarse Aggregate (kg)**	**Super Platisizer (kg)**
Quantity of 1 $m^3$of concrete	143	340	712	1314	1
Mix Ratio	0.42	1	1.99	3.68	0.0024

3.5 EXPERIMENTAL STUDY

3.5.1 COMPRESSION TEST

Compressive strength test, mechanical test measuring the maximum amount of compressive load a material can bear before fracturing. The test piece, usually in the form of a cube, prism, or cylinder, is compressed between the platens of a compression- testing machine by a gradually applied load. This test is allotted as per the rule given in IS 3495-1992. Compression test is that the main and vital test and this test was dispensed by a Compression Testing Machine. This test was carried out on the seventh, fourteenth and twenty eighth day from the day of casting. For mostof the works cubical molds of size 15cm x 15cm x 15cm are commonly used. This concrete is poured in the mold and appropriately tempered so as not to have any voids. After 24 hours, molds are removed, and test specimens are put in water for curing.

Compressive strength = Load
Cross sectional area

Fig 3.11: Compression Strength Testing Machine

3.5.2 SPLIT TENSILE STRENGTH TEST

The concrete tensile strength is the ability of concrete to resist tensile force or stress applied to it. The tensile strength of concrete is measured by the split cylinder test of concrete method. The tensile strength of concrete is measured by the Units of force per crossectional area. The ASTM D638 measures plastics tensile properties including ultimate tensile strength, yield strength, elongation and Poisson's ratio. The most common testing machine used in tensile testing is the universal testing machine. Material Testing. Tensile strength is an important property of concrete because concrete structures are highly vulnerable to tensile cracking due to various kinds of effects and applied loading itself. However, tensile strength of concrete is very low in compared to its compressive strength. This test is allotted as per the rule given in IS:5816-1959. The concrete tensile strength is the ability of concrete to resist tensile force or stress applied to it. The tensile strength of concrete is measured by the split cylinder test of concrete method. The tensile strength of concrete is measured by the Units of Force per Cross-Sectional area (N/Sq.mm. or MPa).

Tensile strength = Load

Cross sectional area

Fig3.12: Split Tensile Strength Testing Machine

3.5.3 FLEXURAL STRENGTH TEST

Flexural testing is used to determine the flex or bending properties of a material. Sometimes referred to as a transverse beam test, it involves placing a sample between two points or supports and initiating a load using a third point or with two points which are respectively call 3-Point Bend and 4-Point Bend testing. Flexural strength is one measure of the tensile strength of concrete. This test is allotted as per the rule given in IS:516-1959. It is a measure of an unreinforced concrete beam or slab to resist failure in bending. It is measured by loading 100 x 100mm concrete beams with a span length 500mm. Most commonly the specimen lies on a support span and the load is applied to the center by the Loading nose producing three point bending at a specified rate. The parameters for this test are the support span, the speed of the loading, and the maximum deflection for the test.

Flexural strength = Load
Cross sectional area

Fig 3.13: Flexural Strength Testing Machine

3.5.4 DEPTH OF PENETRATION OF WATER UNDER PRESSURE

(Water penetration test) Permeability of cement mortar or concrete is of particular significance in structures which are intended to retain water or which come into contact with water. Besides functional considerations, permeability is also intimately related to the durability of concrete, specially its resistance, against progressive deterioration under exposure to severe climate, and leaching due to prolonged seepage of water, particularly when it contains aggressive gases or minerals in solution. The determination of the permeability characteristics of mortar and concrete, therefore, assumes considerable importance. The test consists in subjecting the mortar or concrete specimen of known dimensions, contained in a specially designed cell, to a known hydrostatic pressure from one side, measuring the quantity of of permeability. The test permits measurement of the water entering the specimen as well as that leaving it.

Fig 3.14: Depth of penetration of water under pressure test Apparatus

RESULTS AND DISCUSSIONS

4.1 MATERIAL SPECIFICATIONS

The properties of the cement, fine aggregate and coarse aggregate are briefed.

4.1.1 Cement

The range of specific gravity of cement according to IS 455:1989, Part II is 2.9 to 3.15 and the obtained value for specific gravity of cement is 3.05 which is within the range. The properties of cement are shown below.

Table 4.1 Properties of cement

SINo.	Tests conducted	Values obtained	IS Specification and Allowable limit	Inference
1.	Standard Consistency	32%	IS;4013(PART5)1988, Limit between25%–35%	The obtained value is in between 25%-35%
2.	Specific gravity	3.05	IS;455-1989, limitbetween2.9-3.15	The obtainedvalue isinbetween2.9-3.15
3.	Initial Setting Time	30minutes	IS;4301-1968, Not less than 30 minutes	The obtained value is not Less than 30 minutes

4.1.2 Aggregates

Table 4.2 Properties of fine aggregates

SI No.	Tests conducted	Results	IS Specification and Allowable limit	Inference
1.	Specific Gravity	2.66	IS;2386(Part2)-1963, Limit is between 2.65–2.67	The obtained value is in between2.65-2.67
2.	Sieve analysis	Fineness modulus=3.5	IS383-1970, Limit is between3.1-3.6	The obtained value is in between2-3.5

Table 4.3 Properties of coarse aggregates

SI No.	Tests conducted	Results	IS Specification And Allowable limit	Inference
1	Specific Gravity	2.81	IS2386 (part3), limit is between 2.5-3	The obtained value is in between2.5-3
2	Sieve analysis	Fineness modulus=4.009	IS2386(Part3), limit is in between 4-8	The obtained value is in Between 4-8
3	Water absorption	0.7%	IS2386(Part3), limit is less than 2%	The obtained value is less than2%

4.2 TESTS ON SPECIMEN

4.2.1 Comparison on compressive strength of M30 grade concrete with and without CPF liner

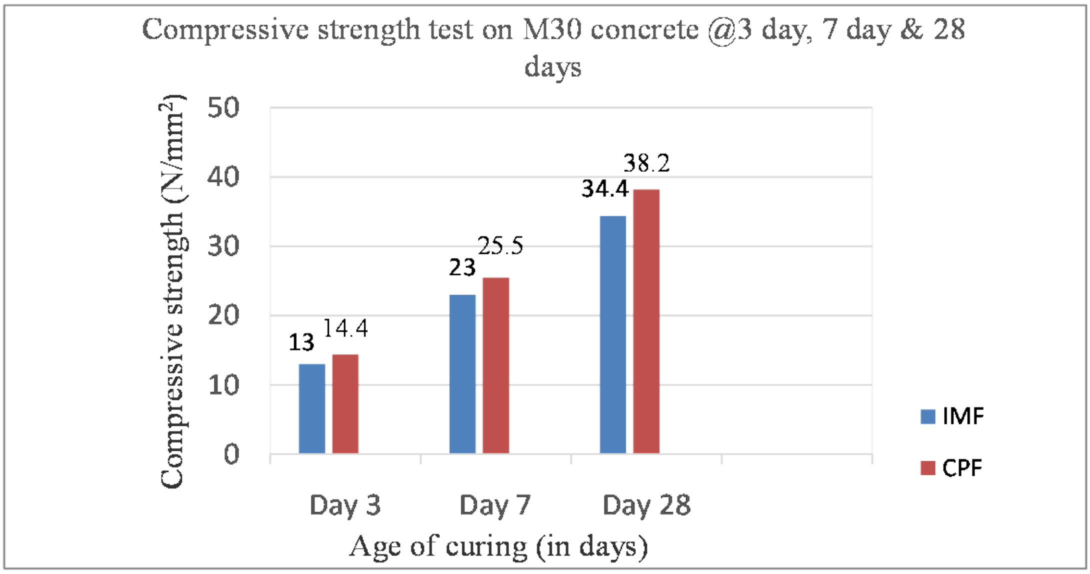
The compressive loading test on concrete were conducted on a compression testing machine of capacity 2000kN. The readings on dial gauge were recorded and compressive strength was calculated. The test was conducted on 150mm cube specimen at 3, 7 and 28 days.

Table 4.4 Compressive strength test result on M30 concrete

AGE OF CURING	COMPRESSIVE STRENGTH WITH OUT LINER (N/mm^2)	COMPRESSIVE STRENGTH WITH LINER (N/mm^2)	PERCENTAGE INCREASE
3 days	13	14.14	8.7
7 days	23	25.5	10.86
28 days	34.4	38.2	11.1

From the obtained results, it is found that the percentage increase in 3day strength of CPF lined concrete is 8.7%, 7day strength is 10.86% and that of 28day strength is 11.1% than IMF specimens.

Fig 4.1: Compressive strength test result on M30 concrete.



4.2.2 Comparison on split tensile strength test of M30 concrete with and without CPF liner

The split tensile strength test on concrete were conducted on a compression testing machine of capacity 2000kN. The readings on dial gauge were recorded and split tensile strength was calculated. The test was conducted on 150mm diameter 300mm height cylinder specimen at 3, 7 and 28 days.

Table 4.5 Split tensile strength test result on M30 concrete

AGE OF CURING	SPLIT TENSILE STRENGTH WITH OUT LINER (N/mm^2)	SPLIT TENSILE STRENGTH WITH LINER (N/mm^2)	PERCENTAGE INCREASE
3 day	1.36	1.43	5.14
7 day	1.94	2.26	16.49
28 day	3.14	3.88	23.56

From the obtained results, it is found that the percentage increase in 3day split tensile strength of CPF lined concrete is 5.14%, 7day strength is 16.49% and that of 28day strength is 23.56% than IMF specimens

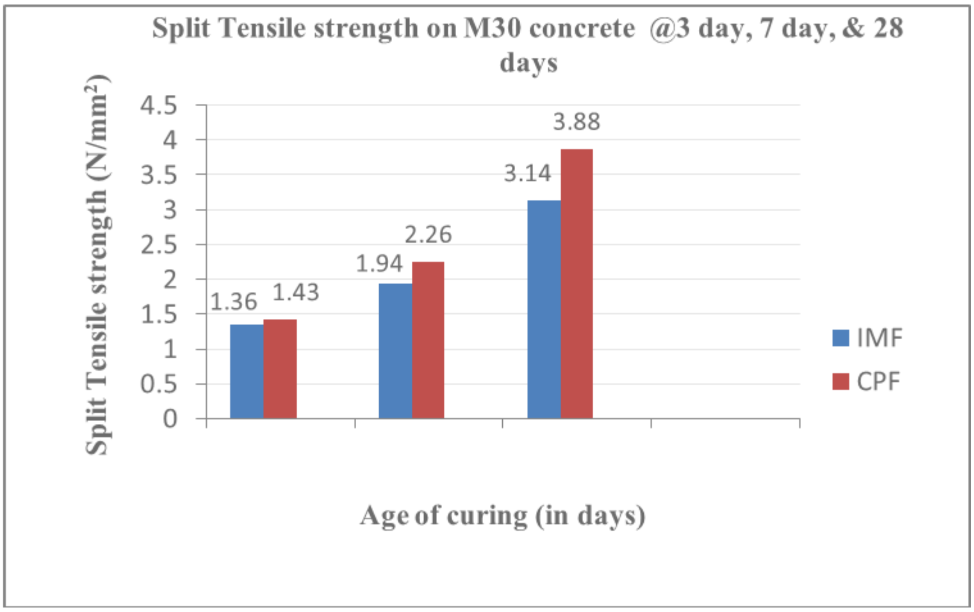


Fig4.2:Split tensile strength test result on M30 concrete.

4.2.3 Comparison on flexural strength test of M30 concrete with and without CPF liner

The flexural strength test on concrete were conducted on a flexural strength testing machine of capacity 2000kN. The readings on dial gauge were recorded and flexuralstrength was calculated. The test was conducted on 500×100×100mm beam specimen at 3, 7 and 28 days.

Table4.6 Flexural strength test result on M30 concrete

AGE OF CURING	FLEXURAL STRENGTH WITHOUT LINER (N/mm^2)	FLEXURAL STRENGTH WITH LINER (N/mm^2)	PERCENTAGE INCREASE
3 day	**3.9**	**4.15**	**6.41**
7 day	**5.2**	**5.6**	**7.69**
28 day	**7**	**7.8**	**11.42**

From the obtained results, it is found that the percentage increase in 3day flexural strength of CPF lined concrete is 6.41%, 7day strength is 16.49% and that of 28day strength is 23.56% than IMF specimens

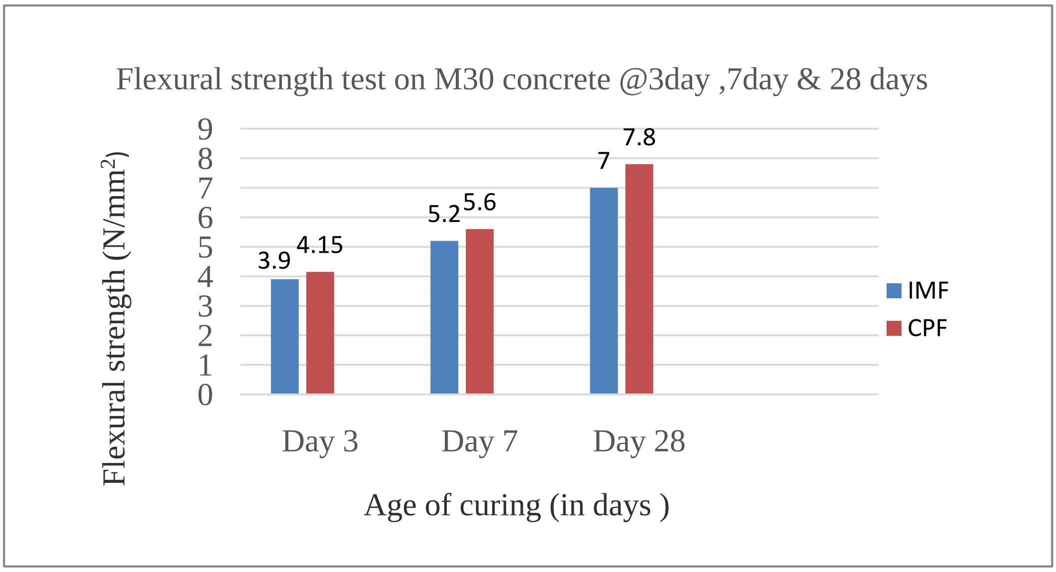


Fig 4.3: Flexural strength test result on M30 concrete.

4.2.4 Comparison on compressive strength test of M35 concrete with and without CPF liner

The compressive loading test on concrete were conducted on a compression testing machine of capacity 2000kN. The readings on dial gauge were recorded and compressive strength was calculated. The test was conducted on 150mm cube specimen at 3, 7 and 28 days.

Table 4.7 Compressive strength test result on M35 concrete

AGE OF CURING	COMPRESSIVE STRENGTH WITHOUT LINER (N/mm^2)	COMPRESSIVE STRENGTH WITH LINER (N/mm^2)	PERCENTAGE INCREASE
3 day	**15.05**	**15.75**	**4.65**
7 day	**22.75**	**24.15**	**5.79**
28 day	**39.9**	**43.5**	**9.022**

From the obtained results, it is found that the percentage increase in 3day strength of CPF lined concrete is 4.65%, 7day strength is 5.79% and that of 28day strength is 9.022% than IMF specimens

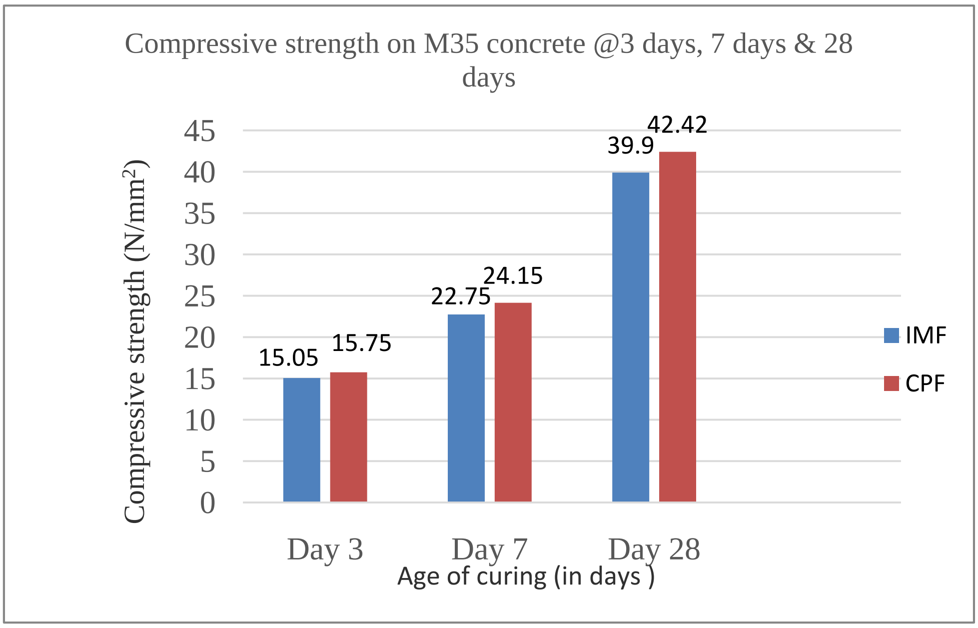


Fig 4.4: Compressive strength test result on M35 cubes.

4.2.5 Comparison on split tensile strength test of M35 concrete with and without CPF liner

The split tensile strength test on concrete were conducted on a compression testing machine of capacity 2000kN. The readings on dial gauge were recorded and split tensile strength was calculated. The test was conducted on 150mm diameter 300mm height cylinder specimen at 3, 7 and 28 days.

Table 4.8 Split tensile strength test result on M35 concrete

AGE OF CURING	SPLIT TENSILE STRENGTH WITHOUT LINER (N/mm^2)	SPLIT TENSILE STRENGTH WITH LINER (N/mm^2)	PERCENTAGE INCREASE
3 day	**2.02**	**2.11**	**2.92**
7 day	**2.36**	**2.64**	**11.86**
28 day	**4.04**	**4.68**	**15.84**

From the obtained results, it is found that the percentage increase in 3day split tensile strength of CPF lined concrete is 2.92%, 7day strength is 11.86% and that of 28day strength is 15.84% than IMF specimens.

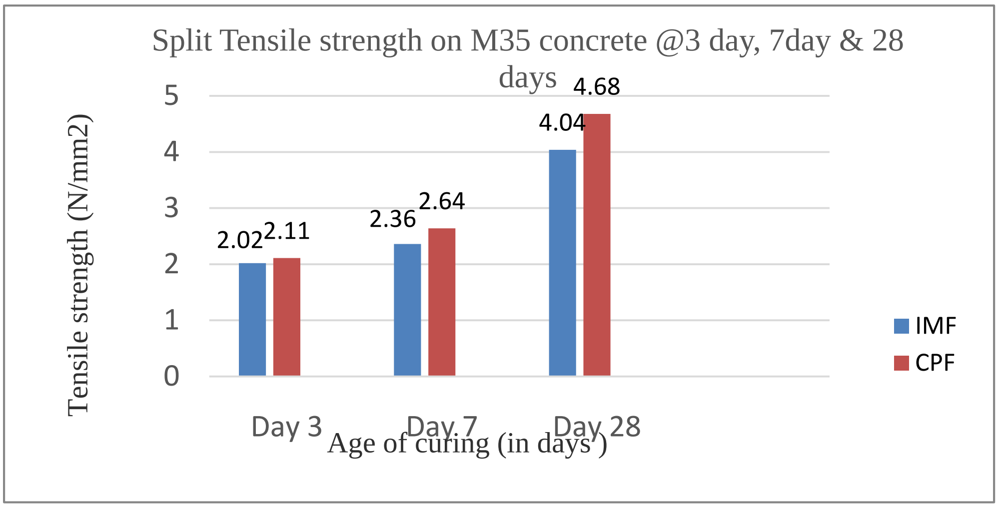


Fig 4.5: Tensile strength test result on M35 concrete.

4.2.6 Comparison on flexural strength test of M35 concrete with and without CPF liner

The flexural strength test on concrete were conducted on a flexural strength testing machine of capacity 2000kN. The readings on dial gauge were recorded and flexural strength was calculated. The test was conducted on 500×100×100mm beam specimen at 3, 7 and 28 days.

Table 4.9 Flexural strength test result on M35 concrete

AGE OF CURING	FLEXURAL STREGTH WITHOUT LINER (N/mm^2)	FLEXURAL STRENGTH WITH LINER (N/mm^2)	PERCENTAGE INCREASE
3 day	**3.25**	**3.41**	**4.92**
7 day	**5.15**	**5.5**	**6.79**
28 day	**8.15**	**8.95**	**9.82**

From the obtained results, it is found that the percentage increase in 3day flexural strength of CPF lined concrete is 4.92%, 7day strength is 6.79% and that of 28day strength is 9.82% than IMF specimens

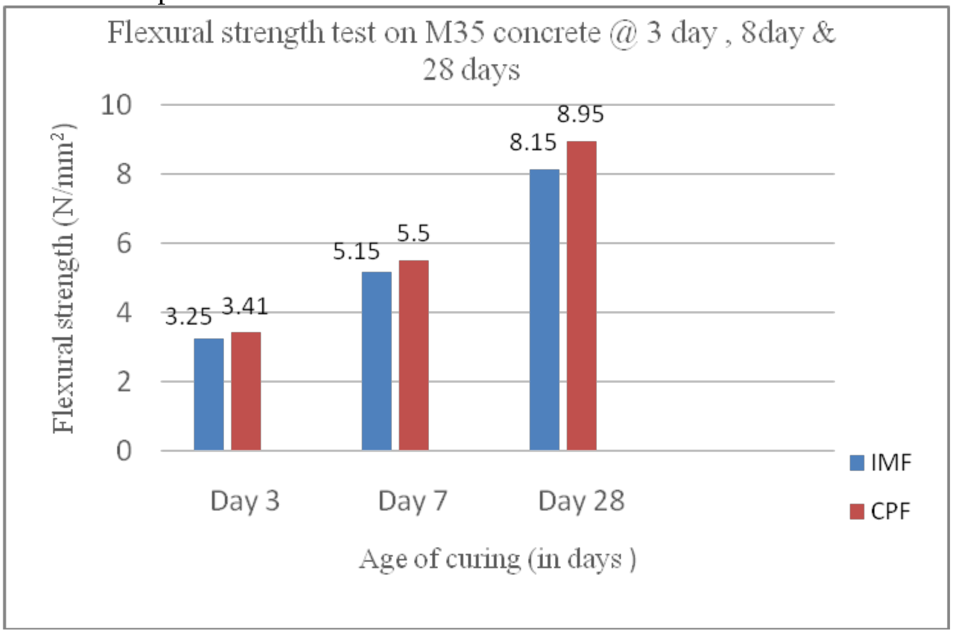


Fig4.6:Flexural strength test result on M35 concrete

4.2.7 Comparison on depth of penetration of water under pressure on both M30 and M35 grade concrete with and without CPF liner

The penetration of water under pressure is tested using the water penetration test apparatus. The test was conducted on 150mm cube specimen at 28day

Table 5 Depth of penetration under water pressure test result on both M30& M35grade concrete

GRADE OF CONCRETE	DEPTH OF PENETRATION WITHOUT LINER (mm)	DEPTH OF PENETRATION WITH LINER (mm)
M30	**15**	**13**
M35	**14**	**11**

It is found from the result that the depth of penetration decreases by the use of CPF liner. There is a decrease2mm depth of penetration on M30 grade concrete and that of 3mm on M35 grade concrete than IMF specimen. The result shows that the CPF lined specimen is more durable than IMF specimen

CONCLUSIONS

The study is conducted to know the effect of permeable formwork on concrete both M30 and M35 grade concrete. The tests conducted are all the strength tests and the durability test. The following conclusions were obtained based the current experimental study:

• It is notified that the use of CPF liner on the formwork act as a filter and reduces the leftover mix water and entrapped air and enhance the quality of surface concrete.

• The compressive strength test were conducted for both M30 & M35 grade concrete, and it is notified that the strength increases by 11% and 9% respectively than IMF specimen.

• Split tensile strength test were conducted for both grades and 23.5% and 15.8% increase in strength were obtained than IMF specimens.

• Flexural strength on M30 & M35 grades increases by 11.42% and 9.8% accordingly.

• Depth of penetration of water under pressure were also found for both M30 and M35 grades and decrease in penetration was noticed. There is a decrease in penetration by 2mm and 3mm respectively.

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