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The effect of controlled permeable formwork liner on the mechanical and durability properties of self compacting concrete

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HIGHLIGHTS

- It is confirmed that adhesive forces are responsible for the water particles to cling to the surface of formwork.
- No other force, such as vibration, hydrostatic etc. is essentially responsible for the water particles to migrate towards the formed surface.
- While conducting compression test on conventional cubes, it inherently causes error to an extent of 3–4 percent.

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ABSTRACT

The quality of the surface zone of concrete is a crucial factor for durable concrete structures, as it is the first line of resistance to penetration of aggressive agencies. Use of controlled permeable formwork (CPF) liner is one of the techniques employed to improve the quality of the surface zone of concrete. 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. It is postulated that CPF drains air and water, which migrate towards the formwork due to vibration caused while compacting concrete and hydrostatic pressure. In the present investigation, an experimental study was carried out to verify the performance and efficiency of CPF liner against self-compacting concrete (SCC). Suitable size specimens were prepared using impermeable formwork (IMF) and CPF liner as well. Tests were carried out to check compressive, split tensile strength and flexural strength; ultrasonic pulse velocity and rebound hammer; abrasion resistance, sorptivity and water absorption. The test results reveal that CPF liner performs equally well with SCC. Vibration/hydrostatic pressure may not play significant role in draining the interface water through CPF liner.

1. Introduction

The quality of the surface zone of concrete is important for reinforced concrete elements, as all the aggressive agents penetrate through the surface zone of concrete to initiate damage. Durability of concrete structure is primarily dependent on the characteristics of surface zone of concrete. To facilitate the process of placing and compaction of fresh concrete, it is necessary to increase the volume of free water slightly above that actually required for complete hydration of cement. It had been postulated that the mix water and the entrapped air would migrate towards the formed surface due to compaction and hydrostatic pressure of concrete [1–3]. As the formed surface is impermeable the water and air are retained at the interface. This causes an increase in water-cement (w-c) ratio at the surface level of concrete and visually the most obvious sign of presence of blowholes, pinholes and surface blemishes following removal of the formwork [2]. The net result of this process would modify the surface zone of concrete with higher w-c ratio and lower cement content than that had originally been contemplated. In other words, the surface zone of concrete would be of poorer quality compared to the bulk concrete [4]. On the contrary, a well compacted dense concrete surface zone is invariably preferred to enhance the durability of RC structures.

The traditional approaches to improve the durability of concrete generally influence the quality of the bulk concrete or more precisely telling, the core concrete. However, the quality of the surface zone of concrete is adversely affected by the type of formwork used during construction. Controlled permeable formwork (CPF) liner is an innovative material employed to improve the quality of the surface zone of concrete. CPF system consists of a textile liner attached on usual formwork as shown in Fig. 1. CPF allows air and

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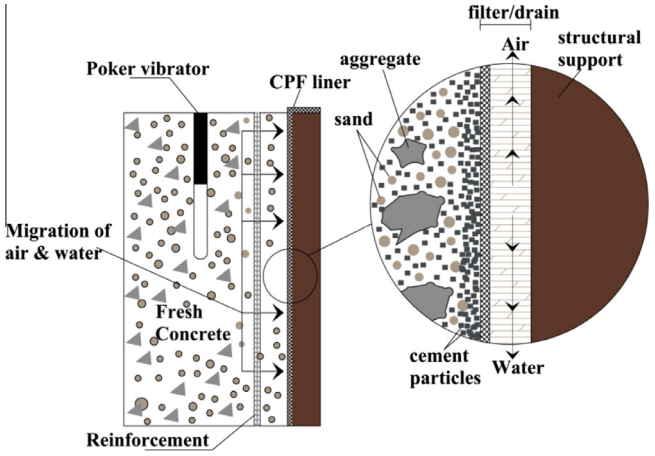

Fig. 1. Controlled permeable formwork – a schematic representation [5].

mix-water to drain out from the concrete surface while retaining cement and other fine particles [3,6,7]. This enables to lower the w-c ratio and enrich of cement content in the near surface zone of concrete. This action creates a uniform and smooth surface, and almost free from blowholes, pinholes and surface blemishes. Further, surface zone of concrete hydrates to a high degree and makes dense surface skin as the CPF liner maintains sufficient moisture which offers a conducive ambiance for effective cement hydration [1,5,8]. A number of researchers have reported that the reduction in w-c ratio, increased cement content and enriched cement hydration in the surface zone of concrete resulted in increase in surface strength, abrasion resistance, freezing and thawing resistance, as well as reduced water permeability, air permeability, water absorption, depth of carbonation, chloride diffusion, and oxygen diffusion [5–40].

Most of the researchers had contemplated that water and air migrate towards the formwork due to the pressure generated during concrete compaction in addition to hydrostatic pressure [41–43,19,18,44–49]. Tanaka and Ikeda [50] reported that immediately after placing the fresh concrete in the formwork, water drains out naturally. However, they did not elaborate the phenomenon behind the process of water drainage through CPF. Under such circumstances the efficiency of CPF liner against self-compacting concrete (SCC) needs thorough verification. In the absence of vibration/compaction of concrete the extent to which water/air get drained out need detailed study. With regard to the effectiveness of CPF against SCC no much work has been reported yet. However, Figueiras et al. [8] reported that the efficiency of CPF liner is similar both in SCC and conventional concrete (CC). They claimed that use of CPF liner made SCC much more durable and sustainable due to synergistic effect. Further, no literature is available on the mechanical properties of SCC made using CPF liner. In general, most of the researchers have exploited CPF liner to study the durability properties of concrete and not on mechanical properties of concrete. The objective of this study is essentially to check the performance and efficiency of CPF liner against SCC and secondly, to verify both mechanical and durability properties of SCC made using CPF liner.

2. Experimental program

2.1. Materials

Concrete was produced using 43 grade Ordinary Portland Cement (OPC) conforming to IS: 8112-1989 [51]. Its specific gravity was 3.14. Locally available river sand conforming to zone II as per IS: 383-1987 [52] was used. Its specific gravity was 2.68 and fineness modulus was 2.54. Crushed stone aggregate conforming to IS: 383-1987 [52] was used. The maximum size of coarse aggregate was 20 mm (graded). Its specific gravity was 2.72 and fineness modulus was 8.15. The tap water available in the Pondicherry Engineering College campus was used and it was conforming to the requirements of IS: 456-2000 [53]. Fly ash obtained from Thermal Power Station, Ennore, Chennai, was used and it was conforming to the requirements of IS: 3812-2013 [54]. In this study polycarboxylate ether polymer based super plasticizer (SP) conforming to IS: 9103-1999 [55] was used. The viscosity modifying admixture (VMA) was also added to increase cohesion and segregation resistance.

2.2. Self compacting concrete mixture proportion

Target strength of 40 MPa was considered in this work. Based on the guidelines of Nan Su [56] the self-compacting concrete mixture was proportioned. Initially trial mixtures were prepared to check the flow properties of SCC, such as slump flow, V-funnel and L-box tests. After adjusting the constituent materials and satisfying the flow properties the composition of SCC was finalised and it is presented in Table 1.

2.3. Controlled permeable formwork (CPF) liner

The CPF liner adopted in this work was type II [3], which was a single layer fabric system. It had two sides, one side acted as filter and other side acted as drain. It was placed over a structural support and tensioned in situ. The specifications of CPF liner as furnished by the manufacturer is given in Table 2.

2.4. Preparation and curing of specimens

Steel moulds were used for casting different concrete specimens. The sides of the moulds were smooth with machine finished surface, which did not require any mould releasing agent. However, a thin coat of oil was applied on the surface of mould and subsequently gently rubbed off with a dry cloth. For CPF specimens, the liner was affixed to the side plates of mould with the glue supplied by the manufacturer (Fig. 2). CPF liner did not require any releasing agent. Demoulding was quite easy due to liner, the moment side face nuts were slightly loosened then the plates had detached from the concrete surface effortlessly. The specimens cast without CPF liner were identified as "IMF" and those made with CPF liner were identified as "CPF".

The concrete mixes were prepared in a drum mixer of capacity 55 L. The moulds were filled with concrete and demoulded after 24 h. The cast specimens were water cured in curing tank till the age of test.

2.5. Testing of specimens

2.5.1. Compressive strength

Cube specimens of 100 mm size were cast to study the effect of CPF liner on strength of concrete. Under each category 12 specimens were cast to find the compressive strength at 7, 14, 28 and 60 days. Three specimens were tested for each test

Table 2
Specifications of CPF liner [57].

Specifications	Unit	Value
Mean pore size	μm	<30
Unit weight	g/m^2	250
Air permeability at 800 Pa	l/s/m^2	250
Tear strength in longitudinal	N	250
Tear strength in transverse	N	200
Thickness at 2 KPa	mm	1.2
Composition	100% polypropylene	

Table 1
Composition of SCC.

Constituent materials (kg/m^3)							Constituent ratios			Fresh properties value		
Cement (C)	Fly ash (F)	Coarse aggregate (CA)	Fine aggregate (FA)	Water (W)	Super plasticizer (SP)	Viscosity modifying admixture (VMA)	$\frac{W}{C}$	$\frac{W}{(C+F)}$	$\frac{CA}{FA}$	Slump (mm)	V-Funnel (s)	L-Box
435	100	860	875	210	5.4	1.0	0.48	0.39	0.98	660	6.70	0.86