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Effect of Controlled Permeable Formwork on Concrete

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Abstract - *In recent years the number of reinforced concrete structures experiencing premature deterioration has grown considerably. It is worth noting that in many cases the structures in question were constructed less than 20 years ago. However, most were designed with an anticipated design life of approximately 100 years. This has forced governments to make provisions in routine maintenance budgets for structural rehabilitation, a process that is both expensive and also disruptive to the travelling public. This paper 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. 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 line 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.*

Key Words: Concrete, Controlled permeable formwork, Structure, Properties

1. INTRODUCTION

Permeable formwork is a special class of lined formwork intended to produce improvements in the strength and durability of the surface of concrete. The bracing and the liner in the formwork are engineered to resist the pressure of plastic (or fresh) concrete, but to allow trapped air and excess water to pass through and be removed during concrete placement and consolidation. The objective in using permeable formwork is to eliminate voids (bug holes) on the surface of the concrete and to increase the strength and durability of the concrete surface immediately behind the formwork.

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. 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. 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. On the contrary, a well compacted dense concrete surface zone is invariably preferred to enhance the durability of RC structures.

2. LITERATURE REVIEW

Philip G. Malone [1] Absorptive or permeable formwork behaves as a filter that allows air and water to escape from the concrete that is directly behind the formwork. The concrete is retained by the filter medium (often a woven or nonwoven fabric); however, air, water, and materials dissolved in the water and very fine suspended solids can escape from the concrete adjacent to the formwork. The water draining through the liner contains a variety of dissolved and fine suspended materials. The liquid extracted from cement paste typically is a saturated calcium hydroxide solution with a pH in the range of 12.5 to 13.5. The fine suspended material can include cement particles, with an average size of 10 µm, and fine mineral admixtures, such as silica fume with an average size 0.1 µm.

Cuicui Chena [2] The concrete surfaces resulting from CPF were blow-hole free with no blemishes but the control one, corresponding to the inner sides of the conventional steel mould walls, presented many blow-holes. Strength from rebound method of concrete from CPF was improved more than 10% than control one. Water sorption and chloride ion penetration of concrete could be restrained if the concrete was casted using CPF due to the denser surface. Pore structure of concrete surface from CPF was modified remarkably, compared with the control one. The porosity of 0-3mm slice was reduced from 10.48% of the Control sample to 7.04% of CPF one. There were many large pores within diameter 10-100um in Control samples, but they could be eliminated by applying CPF.

Reema Goyal , Abhijit Mukherjee [3] The bond between stay-in-place (SIP) composite formwork and concrete has been investigated. Shear tests have been performed to investigate two types of bond mechanisms, aggregate bonding and adhesive bonding. Performance of three different types of adhesives has been reported. Casting of concrete on SIP formwork results in poor bond between them. Surface treatment is necessary to ensure composite action between FRP and concrete. Treatment with resin improves the bond considerably and it is possible to design a system that avoids interface failure and induces failure in the concrete or FRP. Two types of bonding-adhesive bonding and aggregate bonding have been attempted. Their bond performance was comparable. As adhesive bonding is easier to apply it is recommended for construction sites.

S. Kothandaraman, K. Parameshwar Reddy [4] CPF liner performs equally well on Self compacting concrete also. In spite of no vibration being carried out CPF liner had drained out water from the surface of concrete to improve its surface quality. .Surface hardness has also improved by the use of CPF liner. In short, the durability of concrete will be improved by the use of CPF liner. Overall, the improved performance shown by the CPF lined SCC specimens indicate that the CPF liner performs by itself to a great extent and the effect of vibration may have a little effect, which needs further study.

W. Lin, Q. Jiang [5] 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. FEM analysis shows that concrete structure with strengthened surface layer by CPF could significant increase the service life of the structure.

Jiaping Liu [6] Water adsorption of concrete could be restrained by using CPF. It can be explained by several aspects, including disappeared visible defects, reduced w/c ratio of the cover, reduced meso-pores on the concrete surface, and improved pore structures. The concrete surfaces resulting from the CPF were blow-hole free with no blemishes, and large pores on the concrete surface disappeared. However, it was not perfectly even in meso or micro-levels due to the non-uniform CPF surface. Improvement on concrete surface properties made a CPF liner a promising material for civil engineering. However, it might need modification and promotion for CPF to make a better improvement on concrete.

3. ACTION OF PERMEABLE FORMWORK LINERS

The movement of the fluid components through the filter, especially when consolidating the concrete with vibrators, allows the escape of any air trapped immediately behind the formwork and drives out some of the water in the concrete adjacent to the formwork (Figure 1). The goal in using the permeable formwork is to allow air to escape and remove excess water (that is, water above the amount needed to stay at or below the specified value of water-cement ratio). A portion of the fine suspended materials, including cement particles and silica fume, will also be removed with the water. If the vibration is not excessive and the openings in the filter layer are small enough, the loss of cementitious components will not be excessive.

Examination of the concrete directly behind the formwork indicates that the movement of the water in the concrete will result in a decrease in the amount of water in the concrete (lowering the w/c), and fine cement particles from the interior concrete mass will be carried toward the filter layer (increasing the cement factor and further lowering the w/c at the concrete surface).

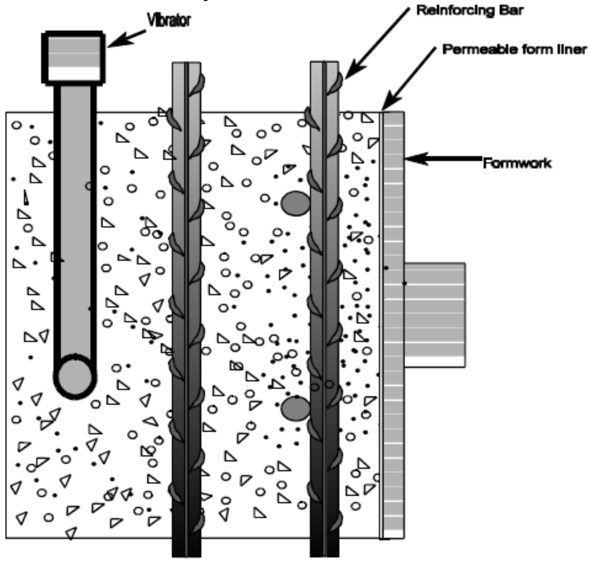

Fig 1: Action of permeable formwork

The general result of the fluid movement toward and through the filter layer in the formwork is that the surface of the concrete is denser and stronger and has fewer bug holes than the same concrete placed in conventional unlined formwork (Figure 2). Most investigations have shown that the influence of the filter layer changes the characteristics of the concrete for a depth of only a few tens of millimeters. The argument has been made that vibration will always result in forcing water to the surface of the concrete mass as the solid particles in the concrete are moved into more compact packing arrangements. As the particles pack together behind conventional formwork, the concrete at the concrete-formwork interface will always have more water than the concrete in the central mass of material. The higher w/c at the surface results in weaker, more permeable concrete at the surface. Filter formwork tends to correct this problem by permitting the water to pass through the concrete-formwork interface and drain out of the formwork.

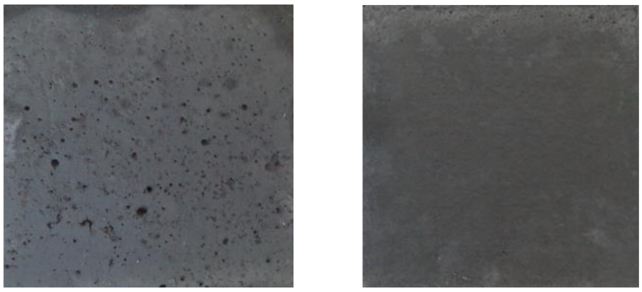

Fig 2 : The surface morphology against impermeable formwork & CPF liner.

Mechanism of a CPF liner:

The three basic elements of a manufactured CPF system, as illustrated within Figure 3 these comprise:

A filter membrane: To allow the passage from the concrete of excess water and air, but designed with a pore size to retain the majority of cement and other small fines.

A drain: Drain through which entrapped water and air may escape.

A structural support: commonly timber, steel or plastic a structural formwork support provides a face against which the CPF system may be attached.

The liner thickness is typically 2.5mm with the filter portion having a pore size of circa 0.050 mm. They are chemically inert and robust with high tear strength and puncture resistance, therefore suitable for many of the harsh conditions that may be encountered on a typical site. It should be stated that due to the polypropylene filter and drain elements been thermally bonded, the use of release agents are not required as the liner easily debond from the concrete whilst remaining attached to the formwork during striking of the shuttering. This has been found to be beneficial for potable water retaining structures as concrete cast against CPF is resistant to bacterial growth in wet/dry environments, Wilson [7].

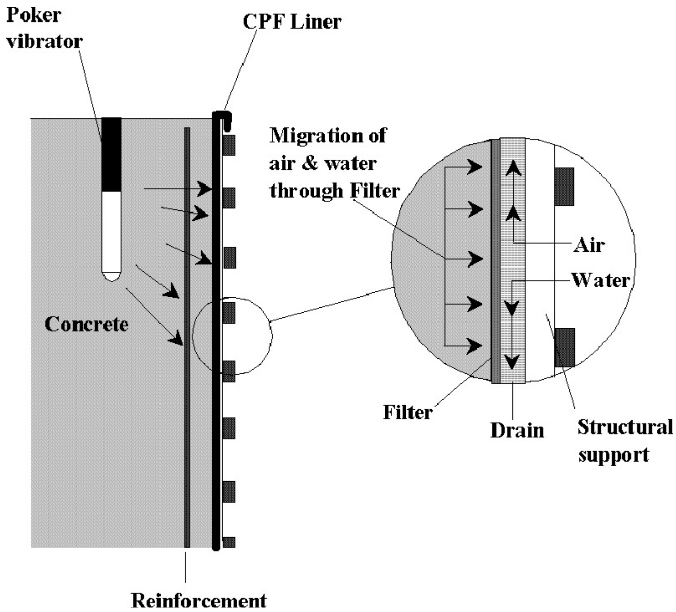

Fig 3: Mechanism of a CPF liner.

4. COMPARATIVE PERFORMANCE OF FABRIC LINERS

All three types of form liners (absorptive panels, woven fabrics, and nonwoven fabrics) are attempting to accomplish the same goal of reducing the w/c in the concrete at the concrete formwork interface. A comparison of representative materials from the three types of formwork liners. All three liner types tested worked well at high w/c's (w/c = 0.65). All produced surfaces that were approximately 40 percent stronger than comparable surfaces cast against conventional (oiled plywood) formwork, as gauged by a surface pull-off test. At lower w/c's (w/c = 0.55), the absorptive panel that was tested produced a softer surface. No attempt was made to measure the absorbance of the panel or develop data on the absorption constant (C-value). Of the two fabric-based systems, the surfaces produced by the nonwoven liner were slightly stronger than those produced by the woven liner.

The absorptive panel could not be reused after the first casting since it absorbed water. When the fabrics were reused, the quality of the surfaces, in terms of both strength and permeability, was reduced. The strength of the surfaces cast against the reused liners was 8 percent lower on the third casting even though the linings were cleaned between castings. Similarly, the water absorption of the surfaces went up and the resistance to abrasion went down after the first use. These laboratory based tests indicate that extreme care will be needed on the job site to ensure that permeable liners are not reused to the extent that the benefits of the form liners become insignificant.

5. INTERACTION OF PERMEABLE FORMWORK AND CONCRETE DURING PLACEMENT AND CONSOLIDATION EXTRACTION OF WATER

One objective of using permeable formwork is to ensure that the optimum amount of water is available in the concrete immediately behind the formwork. A w/c of 0.40 (or lower) is generally considered to be optimum for the production of concrete. Water in excess of that called for by the w/c of 0.40 may be necessary to allow the concrete to be properly placed and consolidated unless a water-reducing admixture is used. One goal of using permeable formwork is to remove enough water from the concrete to lower the w/c from 0.45 or 0.60 to 0.40 or less.

Table 1 presents data on the quantity of water that theoretically should be removed from a 250 mm thick wall in order to reduce the w/c from the w/c at placement (0.45 to 0.60) to a w/c of 0.40 for the entire thickness of the wall. Most of the water leaves the concrete during 90 sec of vibration, and the period of vibration is limited by the tendency of the aggregate in the concrete to separate from the paste. Tests run with concrete having a w/c of 0.50 have shown that well-designed permeable formwork can produce drainage of up to 2.0 L/ m^2 during 90 sec. Water losses of 1 to 2.5 L/m^2. Water loss measurements are tabulated as water drainage from the formwork. Fabric in the formwork can retain up to 0.5 L/m^2 that is removed from the concrete, but not drained. Assuming the concrete was proportioned with 340 kg of water/m^3 and that a water loss of 2.0 L/m^2 affected only the concrete in the outer 20 to 30 mm, the w/c on the surface would be 0.2 to 0.3. The w/c under a permeable liner was 0.35 to 0.40 compared with values between 0.40 and 0.50 for the same concrete placed in conventional wooden formwork. In all cases where careful measurements were made, the permeable formwork reduced the w/c in the surface concrete sufficiently to produce a stronger, denser surface.

Table 1: Volume of water that must be removed from 250mm thick concrete panel to produce a water- cement ratio of 0.40.

Cement Content(kg/m³)	**Excess water, L/m³**		
	w/c = 0.45	**w/c = 0.50**	**w/c = 0.60**
300	4	8	15
400	5	10	20
500	6	13	25

6. SPECIFYING THE SURFACE CHARACTERISTICS DEVELOPED BY PERMEABLE FORMWORK

The quality of the surface will be a function of the preparation of the formwork, the selection of the concrete mixture, and the skill in placing and consolidating the concrete. If a specification is prepared on the basis of the performance of the finished concrete, the acceptance testing must be referenced to test panels that are cast from the same concrete without permeable formwork. Acceptable limits for criteria such as carbonation, resistance to freezing and thawing, and surface hardness have to be indexed to the surfaces cast on conventional formwork that are prepared as controls. For example, examination of test results that have been reported suggest that the surfaces cast against permeable formwork should have a surface that is 10 percent stronger than the surface cast against conventional formwork based on rebound hammer tests (such as ASTM C 805) (ASTM 1998). Similarly, the requirements for resistance to damage from freezing and thawing and the rate of chloride -ion penetration and surface carbonation should be indexed to control surfaces.

Surface coatings applied to concrete typically will not bond well to the new concrete surface due to a layer of soft dusty material on the surface. Preparation for applying a surface coating usually includes wire-brushing or sandblasting to provide a strong surface for coating. Bug holes typically are patched before coating. Concrete surfaces cast against permeable liners typically have a strong, bug hole-free surface, and the coating (usually epoxy or urethane) can be applied directly to the surface without the usual preparation

7. CONCLUSIONS

A review of permeable formwork and its use in placing concrete indicates the following:

a. Properly designed permeable formwork will reduce the w/c in the concrete immediately behind the formwork after the concrete is placed and vibrated. The change can affect concrete to a depth of 25 to 50 mm.
b. The w/c decreases because water can drain away from the concrete immediately behind the permeable formwork and because fine materials including cement collect in the volume of concrete immediately behind the filter layer in the formwork.
c. The decreased w/c in the surface concrete results in the production of a stronger, denser surface that has increased resistance to freezing and thawing, a reduced rate of surface carbonation, a reduced rate of chloride ion Infiltration and increased surface strength.
d. The denser surface produced in concrete cast behind the permeable formwork makes the concrete less sensitive to poor curing practices.

e. Permeable formwork will function with almost any concrete mixture, although a high proportion of fines, such as silica fume in the mixture, may cause the filter to become clogged, and reduce the effectiveness of permeable formwork.

REFERENCES

[1] Philip G. Malone "U.S. Army Engineer Research and Development Center report" Technical Report SL-99-12 -1999.

[2] Cuicui Chena*, Jianzhong Liu a, Gong Cui a, Jiaping Liua"Effect of controlled permeable formwork on the improvement of concrete performances" Procedia Engineering 27 Elesvier (2012) 405 – 411.

[3] Reema Goyal , Abhijit Mukherjee, Shweta Goyal "An investigation on bond between FRP stay-in-place formwork and concrete" Construction and Building Materials 113 (2016) 741–751.

[4] S. Kothandaraman, A. Sarath Kumar, J H. K. Parameshwar Reddy "Durability Performance of Controlled Permeable Formwork on Self-Compacting Concrete" IJETAE(ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 6, Issue 9, September 2016)

[5] W. Lin, Q. Jiang, and J. Liu " Influence of Controlled Permeability Formwork on the Permeability of Concrete" 4th International Conference on the Durability of Concrete Structures 24–26 July 2014

[6] Jiaping Liu , Changwen Miao, Cuicui Chen "E ffect and mechanism of controlled permeable formwork on concrete water adsorption" Construction and Building Materials 39 (2013) 129–133.

[7] Wilson D., Durable Concrete Surfaces, The Role of CPF Liners, Proceedings of Concrete Back to the Future – (Back to Basics/Future Horizons), Glasgow, Scotland, 4 May 2006, pp 81–92.