Majalah Ilmiah Mektek

THE EFFECT OF CONTROLLED PERMEABILITY FORMWORK WITH DIFFERENT CURING METHODS ON THE DURABILITY CHARACTERISTICS OF CONCRETE

Andi Arham Adam*

Abstract

Controlled Permeability Formwork (CPF) can be used to improve the strength, durability and appearance of concrete. This is achieved by allowing excess water and gas to escape at the surface adjacent to the formwork. This paper reports a study aimed at assessing whether such permeable formwork can be used to reduce curing times whilst maintaining durability and strength characteristics. An experimental study is described where trial walls are constructed and tested at various ages following different curing periods and regimes. Results are presented that compare the outcomes of using permeable membrane with those of using a traditional formwork. Comparisons of durability characteristics are were. The durability of the walls was assessed by techniques such as: permeability; and water absorption. Results are presented in terms of how different curing regimes can be employed to achieve equivalent characteristics. A discussion of how such techniques may be used to reduce construction time is presented.

Keyword: *Controlled Permeability Formwork, permeability, absorption*

1. Introduction

It is widely accepted that the surface zone is the major influence on the durability of concrete forming the first line of defense against either physical or chemical deterioration. Aggressive agents penetrate the concrete through the surface zone, thus the transport properties of this zone will determine the rate of penetration into the bulk of the concrete. However, the surface of the concrete is more vulnerable to poor curing and compaction than the bulk of the concrete in the heart of the section (Cairns, 1999). Therefore, a well-compacted strong concrete surface zone is needed with low permeability, low diffusivity and without map cracking. Also an adequate thickness of concrete cover to the reinforcement must be provided. Consequently by improving the permeation properties (absorption, permeability and diffusion) and the strength of the surface zone, one can expect to improve the durability of the whole concrete member.

Traditional approaches to improve the quality of the surface zone are to improve the performance of the bulk concrete by materials selection and controlling mix proportions, however curing is also important and often difficult to control/achieve in practice. Controlled permeability formwork (CPF) is one of the recent developments to improve the quality of the surface zone of the concrete by allowing the bleed water and gas to escape from the concrete surface whilst retaining the cement particles resulting in a denser and less porous concrete surface. The technique reduces the near-surface water/binder ratio and reduces the sensitivity of concrete to poor site curing (Coutinho, 2003).

Although there are several types of CPF systems available on the market, all share the same general principles. According to Price (2000), the basic elements of any CPF system are as follows (Figure1).

- A filter that allows the passage of air and water from the fresh concrete but retains cement and other fine solids
- A drainage system that transfers the air and water removed from the fresh concrete to outside the formwork
- A structural support that supports the filter and drainage elements and also maintains the required formwork profile and resists the concrete pressure

---

[*] Staf Pengajar Jurusan Teknik Sipil Fakultas Teknik Universitas Tadulako, Palu

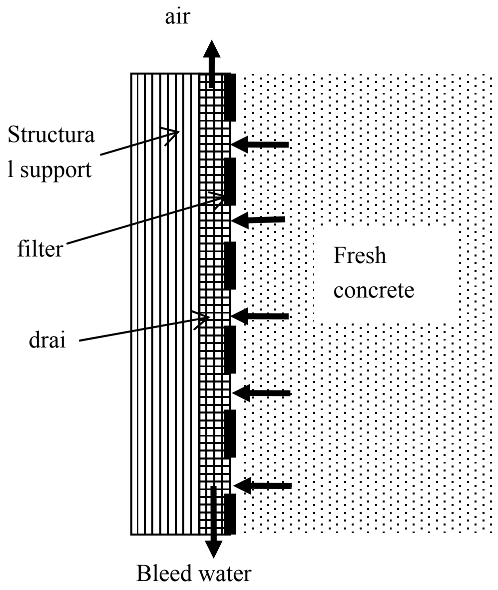

Figure 1. General elements of a CPF system (Price, 2000)

Price (2000) classified the CPF system into three general classifications:

– Type I. Two-layer filter fabric systems that are fixed over a structural support and tensioned in-situ. These systems can be reused with careful cleaning between uses. Two CPF systems of this category are silk form and textile form
– Type II. A single-layer filter fabric system that is fixed over a structural support and tensioned in- situ. These systems are generally single-use products. Formtex and Zemdrain are examples of this type.
– Type III. A two-layer system combining a filter fabric bonded to a backing grid. This type of CPF is fixed onto a structural support, but does not need tensioning. The filter fabric is pre-tensioned in the manufacturing process and tension is maintained by the backing grid. This type can be used more than once. Zemdrain MD is one of this class.

The aim of the research carried out is to assess whether the controlled permeability formwork can be used to reduce curing times whilst maintaining durability and strength characteristics of concrete.

2. Experimental Details

2.1 Materials

General Purpose (GP) Cement, supplied by Cement Australia in according to AS 3972 (1997) was used in this study. The coarse aggregates used were natural river gravel with 10 mm maximum size, while the fine aggregates were natural river sand with 80% passing a 600 µm sieve. Both coarse and fine aggregates were prepared in accordance with AS 2758.1 (1998)

The controlled permeability formwork liner adopted was Formtex manufactured and marketed by Fibertex. The physical properties of the liner are shown in Table 1.

Three moulds of 200mm x 600mm x 600mm (high) made from Plywood were used in this experiment. Two moulds had CPF liner attached on the 600 x 600 face to form the Controlled Permeability Formwork system while the other mould was used as traditional formwork – offering a timber surface.

Table 1. Physical properties of Formtex (as provided by the manufacturer)

Physical properties	Unit	value
Pore size	µm	<30
weight	g/m^2	250
Air permeability at 800 Pa	$l/sec/m^2$	250
Tear strength machine direction	N	250
Tear strength machine direction	N	200
Thickness at 2 kPa	mm	1.2
Composition	100% polypropylene	

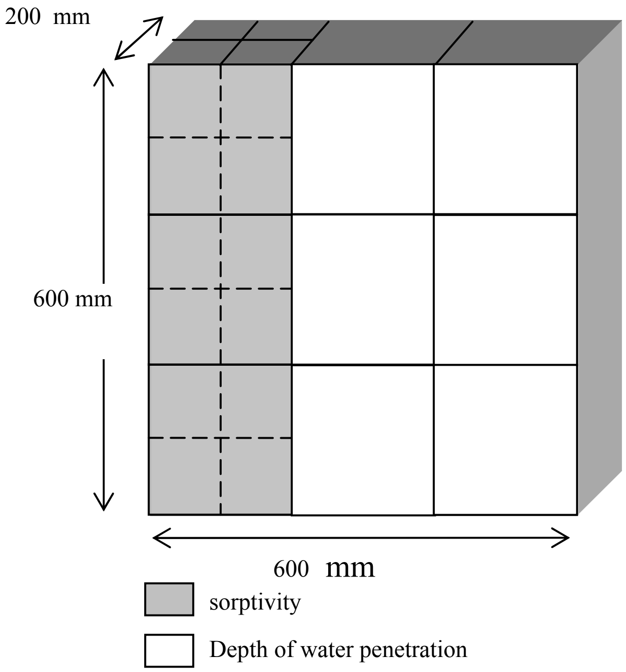

Figure 2. Specimen dimension, cutting positions and tests.

2.1 Mix proportion

The mix design in this experiment was based on the British Department of the Environment document (1988). The mix proportion are tabulated in Table 2.

Table 2. Proportions of the mix

Water	193 kg/m3
Cement	402 kg/m3
Coarse aggregate	
10-mm	419 kg/m3
20-mm	838 kg/m3
Sand	532 kg/m3

2.3 Specimens details

Three specimens of 200mm x 600mm x 600mm (high) as shown in Figure 2. were cast in this experiment. Two specimens were cast with CPF whilst the other was constructed in traditional formwork. The 2 character notation adopted is as follows:

- First character : C = CPF; W= Plywood formwork
- The second character (a number and letter): 1S =1 day curing with wet hessian; 14S=14 days curing with wet hessian.

2.4 Mixing, curing, and cutting

The mixing was performed in accordance with AS 1012.2 (1994) using dry aggregate and a pan mixer. The fresh concrete was poured into the special moulds in three layers. After pouring, poker vibration was applied to each layer to assist the draining of the excess water through the CPF liner. The formwork was removed 24 hours after casting for all specimens. Two specimens (CPF and ordinary formwork) were then cured by covering them with wet hessian and polyethylene sheet for 14 days, the other CPF specimen was cured for 1 day. After the period of curing, the specimens were exposed to the laboratory environment. At the age of 28 days, the specimens were cut using a concrete diamond saw. Six blocks of 200 x 200 x 200 mm were cut from different levels of the specimens (bottom, middle, and top) and tested for water penetration depth. The remaining 24 blocks of 100 x 100 x 100 mm were tested for sorptivity.

2.5 Test program

- Sorptivity test

The sorptivity tests were undertaken in accordance with DIN 52617 (1987). Samples of 100 x 100 x 100 mm were dried to a constant weight. The samples were weighed to obtain the dry weight of the sample and then immersed face down in water to a depth of 2-5 mm. The sides of the specimens were coated with epoxy to allow free water movement only through the bottom face (unidirectional flow). At intervals of 5, 10, 30, 60 minutes, and then hourly to 4 hours after the start of the test, the specimen was removed from the tray, the surplus water wiped off with tissue paper, and the specimen weighed to the nearest 0.1 g and then returned to the tray. The results were plotted against the square root of the time to obtain a slope of the best fit straight line.

According to Hall (1989), the penetration of water under capillary action can be modeled by:

$$I = A + St^{1/2} \qquad \dots\dots\dots\dots\dots\dots\dots\dots(1)$$

where I is the cumulative absorbed volume after time t per unit area of inflow surface, $I = Dw/a$r, Dw being the increase in weight, a the cross-sectional area and r the density of water.

It was found that the experimental data plotted against $t^{1/2}$ was very well represented by a straight line with s (water sorptivity in mm/ min$^{1/2}$) being the slope of the line. In this test program, Equation 1 was used to determine the water sorptivity of concrete by linear regression.

- Depth of water penetration

The depth of water penetration was assessed in accordance to DIN 1048 (1990) using a concrete impermeability apparatus (as shown Figure 3). Concrete samples were placed inside the permeability cells and a water pressure of 100kPa was applied to the samples for two days followed by 300kPa and 700kPa for one day each. At the end of this period, the test samples were removed from the cells, surface dried, and split in half perpendicular to the injected face. The average depth of penetration was noted and was used as an indication of the permeability of the concrete.

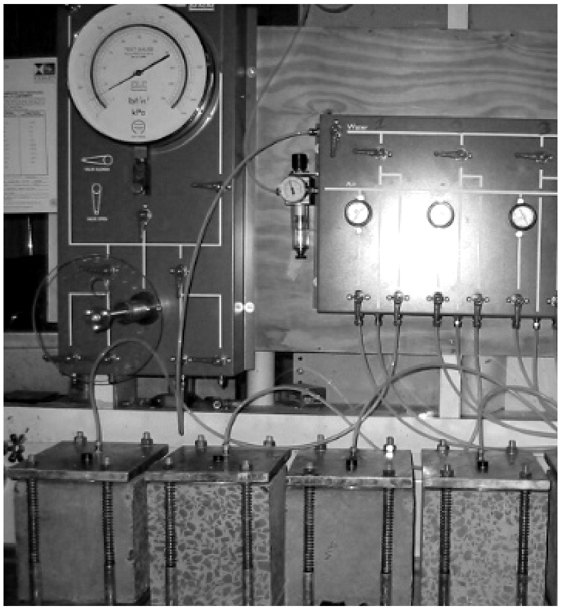

Figure 3. Concrete permeability apparatus

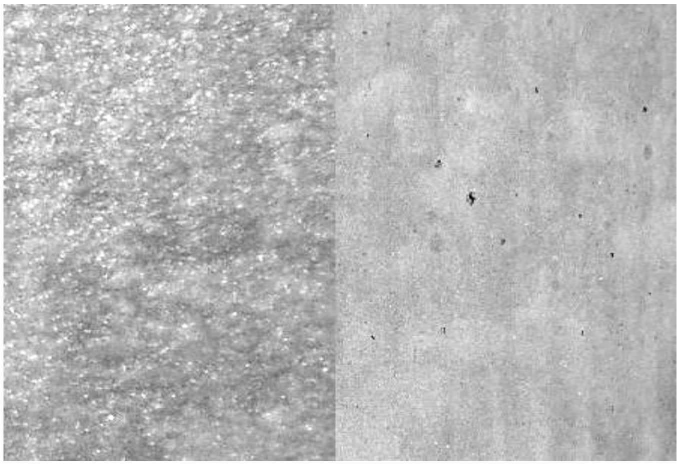

Figure 4. Surface appearance of specimens cast with CPF (left) and with ordinary formwork (right)

3. Results and Discussion

3.1 Surface Appearance

The visual appearance of concrete cast with the CPF was textured and dark in colour whereas for the concrete cast with ordinary formwork the appearance was dustier and lighter in colour. In terms of blowholes, only a few were found in the CPF specimens (near the top) while in the specimens from the traditional formwork blowholes appeared throughout (Figure 4).

The results of the sorptivity tests are presented in Table 3 and Figure 5. The water gained during the sorptivity test was plotted against the square root of time and the slope of the straight line was obtained by regression analysis. The sorptivity of the samples can be determined from the mathematical model as defined in Equation 1.

The results of the regression analysis are shown in Table 3 - a very good fit to data was obtained with coefficients of correlation (R) of over 0.99. The sorptivity index (S) from Table 3 are presented in Figure 5.

The sorptivity values in Figure 5 indicate that CPF reduces the sorptivity of the concrete surface zone despite a shorter period of curing (1 day for C1S compared to 14 days for W14S). For the same length of curing period (14 days), the reduction of sorptivity due to the adoption of CPF (C14S) was 38% at the top and middle and 43% at the bottom level.

It can also be seen from Figure 5 that the CPF is more effective in the lower level of the specimens due to the higher hydrostatic pressure.

Table 3. Sorptivity (mm/min$^{1/2}$)

Level	**Sample**			**Reduction* (%)**
	C1S	**C14S**	**W14S**	
Top	0.157	0.132	0.214	38
Middle	0.145	0.129	0.208	38
Bottom	0.120	0.113	0.200	43

*for the same length of curing – 14 days

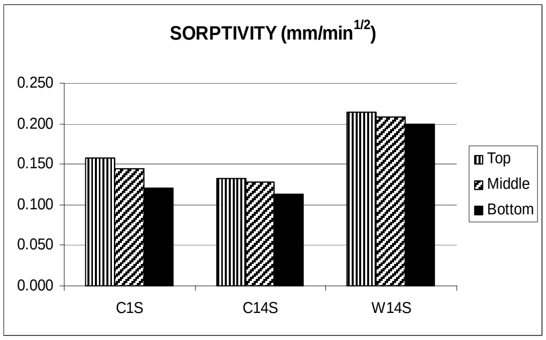

Figure 5. water absorption by capillarity of concrete cast with CPF and ordinary formwork with different curing periods

3.3 Depth of water penetration - permeability

The depth of water penetration (Table 4 and Figure 6) was reduced by the application of CPF to approximately half for the same length of curing. Furthermore, even with the shorter curing period (1 day), the concrete cast with CPF shows a significant reduction in the depth of water penetration compared to the concrete cast with ordinary formwork (after 14 days).

The effect of hydrostatic pressure was also apparent in the CPF specimens (C1S and C14S). However for concrete cast with ordinary formwork (W14S) there was a greater increase in depth of water penetration with hydrostatic pressure (depth from the top) due to the effect of the bleed water which tends to move upwards. In such cases, the top level of the specimens may be porous and permeable due to an accumulation of water and air at the interface with the formwork.

Table 4. Depth of water penetration (mm)

Level	**Sample**			**Reduction***
	C1S	**C14S**	**W14S**	**(%)**
Top	70	60	130	54
Middle	60	50	105	52
Bottom	50	45	90	50

*for the same length of curing – 14 days

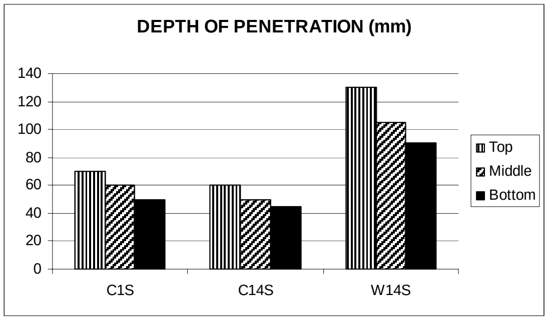

Figure 6. permeability as water penetration depth of concrete cast with CPF and ordinary formwork with different curing periods

4. Conclusions

- It can be concluded that in general the use of CPF improves the quality of the concrete in the surface zone.
- The improvement achieved by the adoption of the CPF is mainly due to the ability of the system to drain the bleed water thereby reducing the water/cement ratio in the concrete surface zone.
- CPF tends to improve the quality of the concrete surface zone when compared to traditional formwork despite reduced curing time. Consequently adoption of CPF could be used to reduce construction time in suitable cases.

5. References

Australian Standard AS 1012.2. 1994. *Methods of testing concrete - Preparation of concrete mixes in the laboratory*. Australian Standard Association

Australian Standard AS 2758.1. 1998. *Aggregates and rock for engineering purposes - Concrete aggregates.* Australian Standard Association

Australian Standard AS 3972. 1997. *Portland and blended cements*. Australian Standard Association

British Standard BS 1881-202. 1986. *Testing concrete - Recommendations for surface hardness testing by rebound hammer*. British Standard Institution

Cairns, J. 1999. Enhancements in surface quality of concrete through use of controlled permeability formwork liners. *Magazine of Concrete Research* 51(2): 73-86

Coutinho, J. S. 2003. The combined benefits of CPF and RHA in improving the durability of concrete structures. *Cement & Concrete Composites* 25: 51-59

DIN 1048. 1990. *Test Methods of Concrete Impermeability to Water: Part 2.* Deutscher Institut Fur Normung,

DIN 52617. 1987. *Determination of the water absorption coefficient of construction materials*. Deutscher Institut Fur Normung,

Hall, C. 1989. Water sorptivity of mortars and concretes: a review. *Magazine of Concrete Research* 41(147): 51 – 61

Price, W. F. 2000. *Controlled permeability formwork*, CIRIA C511

Teychenne, D.C., Franklin, R.E., Erntroy, H.C., 1988. *Design of normal concrete mixes*. Department of the Environment Building Research Establishment Transport and Road Research Laboratory.