Effect of water curing duration on strength behaviour of portland composite cement (PCC) mortar

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Abstract. Cement manufacturing of Indonesia has been introduced Portland Composite Cement (PCC) to minimize the rising production cost of cement which contains 80% clinker and 20% mineral admixture. A proper curing is very important when the cement contains mineral admixture materials. This paper reports the results of an experimental study conducted to evaluate the effect of water curing duration on strength behaviour of PCC mortar. Mortar specimens with water to cement ratio of (W/C) 0.5 were casted. Compressive strength, flexural strength and concrete resistance were tested at 7, 28 and 91 days cured water. The results indicated that water curing duration is essential to continue the pozzolanic reaction in mortar which contributes to the development of strength of mortar made with PCC.

1. Introduction

Cement manufacturing companies in Indonesia has been introduced Portland Composite Cement (PCC) to minimize the rising production cost of cement. The PCC equivalent with CEM Type II/A-M cement which contains 80% clinker and 20% mineral admixture including ground granulated blast furnace slag, silica fume, fly ash and gypsum. The use of the PCC on concrete production requires a proper curing due the presence of mineral admixture. Although it is very simple and inexpensive procedure, proper initial curing has an important influence on improving the concrete quality [1-2]. The objective of curing is considered by the duration of providing concrete with sufficient humidity and appropriate temperature conditions to reduce the loss of moisture to ensure the progress of hydration reactions causing the filling and segmentation of capillary voids by hydrated compounds [3-4]. The matter would be more critical in the case of the cement containing supplementary cementitious material because the pozzolanic reaction is very sensitive to the curing procedure. According to the ACI Committee 308 [5], the curing period should be extended to 14 days when the cement contains supplementary cementitious materials, owing to the slow hydration reactions between supplementary cementitious materials and the calcium hydroxide. Furthermore, curing condition also could be an important parameter in controlling durability of the reinforced concrete exposed to the marine environment [6].

In this study, the effect of water curing duration on strength behaviour of mortar made from PCC was evaluated. Mortar specimens with water to cement ratio of (W/C) 0.5 were casted. Compressive strength, flexural strength and concrete resistance were tested at 7, 28 and 91 days cured water.

2. Experimental procedure

2.1. Material and mix proportion

Portland Composite Cement (PCC), Ordinary Portland Cement (OPC), washed sea sand were used and physical properties of material is shown in table 1. Further, the chemical compounds of the PCC and OPC is presented in table 2. For all specimens a mortar mix with water to cement ratio (W/C) 0.5 was casted. The mix proportion of mortar used is described in table 3.

Table 1. Physical properties of materials.

Material	Description
Portland Composite Cement (PCC)	SSD density = 3.08 g/cm^3 Specific surface area (SSA)= 3410 cm^2/g
Ordinary Portland Cement (OPC)	SSD density = 3.16 g/cm^3 Specific surface area (SSA) = 3390 cm^2/g
Washed sea sand	SSD density = 2.58 g/cm^3 Fineness modulus (F.M) = 2.77

Table 2. Chemical compounds of cement.

Chemical compounds (%)	PCC	OPC
Magnesium oxide (MgO)	0.99	1.2
Sulfur trioxide (SO_3)	1.81	2.23
Silicon dioxide (SiO_2)	18.39	19.71
Aluminium oxide (Al_2O_3)	5.15	5.20
Ferric oxide (Fe_2O_3)	3.14	3.73
Calcium oxide (CaO)	61.79	62.91
Loss of ignition (LOI)	4.61	2.15

Table 3. Mix proportion of mortar.

W/C	Water (kg/m^3)	Cement (kg/m^3)	Sand (kg/m^3)
0.5	255	510	1508

2.2. Mixing and curing

Water and cement were first placed in a standard mortar mixer and mixed for about 1 min. Then, the sands were added and mixed for 2 min. Finally, the mixture was mixed for an additional 2 min to complete the whole mixing process. The fresh mortar samples were then put into the steel moulds in two layers of similar depths. After filling up each layer, compaction was achieved by placing the moulds on a mechanical vibrating table. Thereafter, the mortar specimens were covered with a plastic sheet and allow to cure in the laboratory environment at 20 ± 2 ºC for 24h. After 24h, the samples were demoulded and cured in water until further testing.

2.3. Specimens and testing

The flow table test was used for determining the fluidity of fresh mortar mix as described by ASTM C1437 [7]. A three-point flexural strength test in conformity with ASTM C348 [8] was performed at 7, 28 and 91 days on prism specimens with a size of 40 x 40 x 160 mm (figure 1). The remaining portions of the broken prisms in the flexure strength test were used for determining the equivalent compressive strength according to ASTM C349 [9] as shown in figure 2. In addition, the electric resistance of mortar was measured on prism specimen (40 x 40 x 160 mm) with steel bar of 10 mm in

diameter centrally located with a length of 120 mm. Mortar resistance was performed by immerse method using portable rebar corrosion meter as shown in figure 3.

Figure 1. Three-point flexural strength test

Figure 2. Compressive strength test

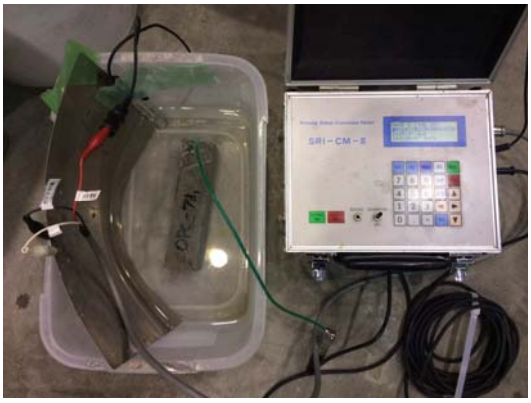

Figure 3. Mortar resistance measurement

3. Results and discussion

3.1. Slump flow

The slump flow results of the fresh mortar mixes are shown in figure 4. The results show that the PCC decreased the fluidity of the mortar due to the higher surface area of PCC than OPC which cause low workability. The slump flow of PCC and OPC mortar were 160 mm and 165 mm, respectively.

3.2. Flexural strength

The flexural strength of PCC and OPC mortar was determined at the ages of 7, 28 and 91 days. Figure 5 shows the development of flexural strength with age for PCC and OPC mortar. The flexural strength of PCC mortar is found lesser than of OPC mortar at all the ages, which could be attributed for slow hydration process of PCC. The percentage increase in flexural strength from 7 to 28 days and 28 days to 91 days has been 4.95% and 6.32%, respectively for OPC mortar. The increase in strength for similar comparison is observed as 12.37% and 14.36%, respectively for PCC mortar.

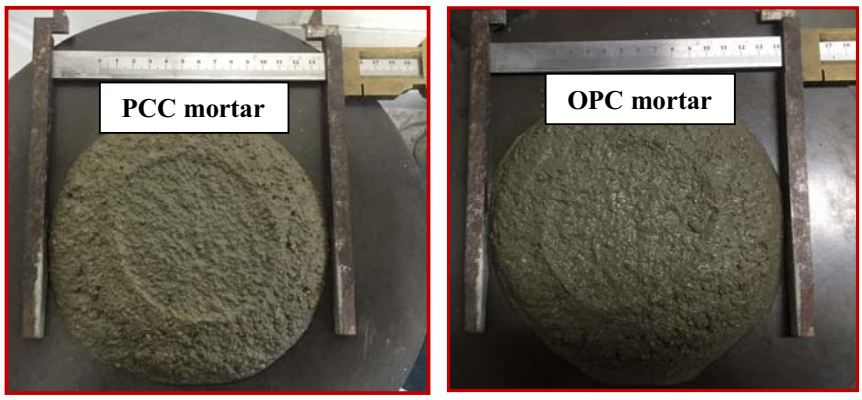

Figure 4. Slump flow of PCC and OPC mortar

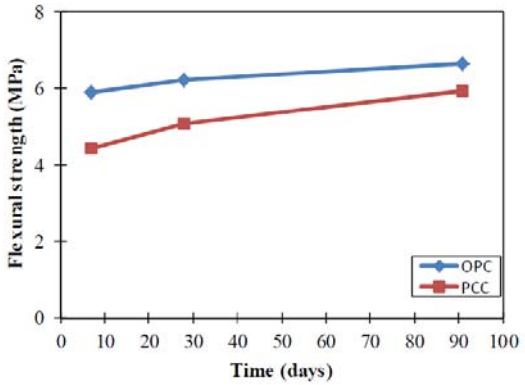

Figure 5. Flexural strength of mortar specimens

3.3. Compressive strength

Figure 6 show the development of compressive strength of PCC and OPC mortar at 7, 28 and 91 days cured water. The compressive strength of mortar increased with increasing curing time. Test results showed that the 7 days compressive strength for OPC mortar is 25.05% higher than PCC mortar. At 28 days, PCC and OPC mortar reached the compressive strength about 34.38 MPa and 42.19 MP. A significant increasing in compressive strength of PCC mortar was noticed at 91 days. The PCC mortar shows that compressive strength is almost identical with that of OPC mortar after 91 days cured water. This indicate that PCC mortar have lower strength than OPC mortar at early ages (7 and 28 days), but achieved similar compressive strength at 91 days.

3.4. Resistivity measurement

The resistivity of PCC and OPC mortars specimens at 7, 28 and 91 days are shown in Figure 7. Similar trends to that flexural and compressive strength can be observed. The resistivity of mortar increased with increasing curing time. The resistivity of PCC and OPC mortar is found similar at 7 days. At 28 days, OPC mortar showed higher resistivity value than PCC mortar due to the slow hydration process in the presence of mineral admixture of PCC. But at later ages, the resistivity of PCC and OPC mortar is almost same.

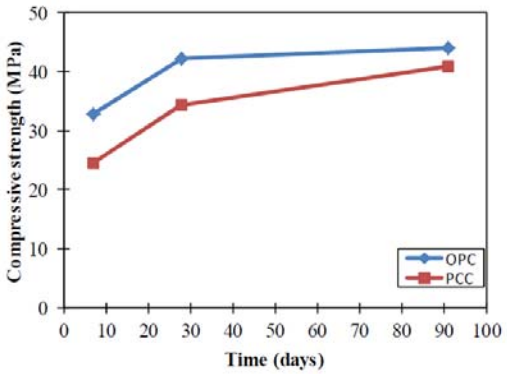

Figure 6. Compressive strength of mortar specimens

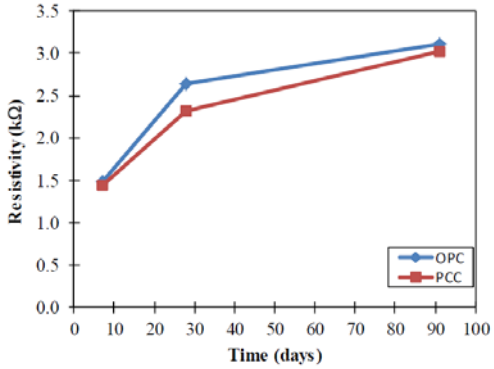

Figure 7. Resistivity of mortar specimens

The properties of mortar are significantly influenced by duration of curing since it greatly effects the hydration of cement. A proper curing maintains a suitably warm and moist environment for the development of hydration products and thus reduces the porosity in hydrated cement paste and increases the density of microstructure in mortar [10]. The chemical composition of the calcium silicate formed in hardened blended cement paste was different from that of Portland cement hydration products. For this reason, mortar made with PCC will have lower strength than OPC at early ages and reached almost similar strength at longer ages of curing (91 days).

4. Concluding remarks

This experimental study has investigated the effect of water curing duration on strength behaviour of Portland Composite Cement (PCC). The strength at early ages of PCC mortar is lower than that of OPC mortar whereas, at later ages both of the mortar is providing approximately similar strength due to continuous curing condition and well performed pozzolanic reaction activities. It can be concluded that adequate curing at early ages as well as later ages is essential to continue the pozzolanic reaction in mortar which contribute to the development of strength of mortar made with PCC.

5. References

[1] Alizadeh R, Ghods P, Chini P, Hoseini M, Ghalibafian M and Shekarchi M 2008 Effect of curing condition on the service life design of RC structures in the Persian Gulf Region *Journal of Materials in Civil Engineering* **20** 2-8.

[2] Radlinski M and Olek J 2015 Effects of curing conditions on the properties of ternary (ordinary portland cement/fly ash/silica fume) concrete, *ACI Material Journal* **112(1)** 49-58.

[3] Guneyisi E, Ozturan T and Gesoglu M 2005 A study on reinforcement corrosion and related properties of plain and blended cement concretes under different curing conditions, *Cement and Concrete Composites* **27** 449-461.
[4] Guneyisi E, Gesoglu M, Ozturan T and Ozbay E 2009 Estimation of chloride permeability of concretes by empirical modelling: Considering effects of cement type, curing condition and age *Construction and Building Materials* **23** 469-481.
[5] ACI Committee 308 2009 *Recommended practice for curing concrete* (MI: MCP, American Concrete Institute) Farmington Hills
[6] Caronge M A, Hamada H, Irmawaty R, Sagawa Y and Yamamoto D 2015 Application of sacrificial anode for prevention of steel corrosion in cracked concrete *Journal of Advanced Concrete Technology* **13** 479-488.
[7] ASTM C1437 2007 *Standard test method for flow hydraulic cement mortars* (ASTM International) West Conshohocken PA
[8] ASTM C348 2008 *Standard test method for flexural strength of hydraulic cement mortars* (ASTM International) West Conshohocken PA
[9] ASTM C349 2008 *Standard test method for compressive strength of hydraulic cement mortars (using portions of prisms broken in flexure)* (ASTM International) West Conshohocken, PA.
[10] Uddin Md A, Jameel M, Sobuz H R, Islam Md S and Hasan N Md S 2013 Experimental study on strength gaining characteristic of concrete using portland composite cement, KSCE *Journal of Civil Engineering* **17(4)** 789-796.