Effect of added the polycarboxylate ether on slump retention and compressive strength of the high-performance concrete

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Abstract. It is well known that workability of high performance concrete (HPC) is dependent on slump value of concrete mixture. Moreover, slump retention is the most sensitive compared to a well-known slump value because it represents the durability of concrete mixture for its applications in the field of civil engineering. This research used the polycarboxylate ether (PCE) to increase slump value of concrete mixture and then verified the effect of PCE on the slump retention and compressive strength of different high-performance concretes. 0%, 0.5%, 1%, 2% of PCE were added into concrete mixture to yield a minimum compressive strength of f'c 50 MPa. The slump retention tests were performed at 0, 15, 30, 45, 60 and 75 minutes while the compressive strength tests were carried out at 3, 7, 14 and 28 days for every concrete sample. The result findings showed that the optimal concrete performance can be achieved by adding 2% of PCE to reach at a slump retention value of 45 minutes and a compressive strength of 53.84 MPa. Effect of PCE on the slump retention and compressive strength has been verified to contribute an insight into the application of a proper designed workability of HPC.

1 Introduction

The needs of high performance concrete (HPC) for construction in Indonesia will increase from the year to year due to the government policies have been aligned to focus on infrastructure development as foundation for dynamic economic growth. However, many constraints faced by concrete producers in the manufacturing of HPC should have to look at a dedicated solution. One is how HPC can retain its existing slump retention capability to ensure that the application of HPC in civil engineering industry can achieve the best performance with high workability. Many recent studies highlight established applications

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of nanoparticles such as silver nanoparticles, titania polyvinylalcohol–alginate beads, and polycarboxylate ether (PCE) as superplasticizer to rapidly emerging applications in the civil and environmental engineering and discuss future research directions [1-3]. Therefore, it has been reported that the addition of superplasticizer can improve the workability of HPC by using a very low w/c ratio [4].

Many manufacturers can produce the HPCs of being characterised with a long period of slump retention for maintaining the existing concrete workability. The use of superplasticizer has been proven to be effective in fabricating a long retardation concrete setting and long slump retention. However, uncontrolled use of the PCE as superplasticizer to improve the workability can cause a low compressive strength of the HPC [5].

Further the quantity of superplasticizer added to a concrete mixture is a concern for many producers of HPC in civil engineering industry due to the role of superplasticizers during the hydration of cement is very complex and is still not fully understood [6]. It is suggested that the importance is how to adjust the quantity of PCE added to get a proper mixture of HPC to produce a long slump retention and high compressive strength value [7]. Therefore, the objectives of this study are (1) to obtain a proper quantity of PCE added into concrete's mixture for obtaining optimal composition of HPC and (2) to assess the performance of HPC as it can be verified from the values of long slump retention and high compressive strength. The benefit of this research can help producers in manufacturing HPC with an optimal composition of PCE.

2 Materials and methods

2.1 Materials

This paper evaluates the effects of PCE level in concrete mixture and experimental method on the observed HPC performance of measured using different compositions of PCE with a concrete mix design of added 0% of PCE as the reference. This study used the materials of (1) type-1 Ordinary Portland Cement (OPC), (2) coarse aggregate of quarry Purwakarta, (3) fine aggregate from Galunggung quarry and (4) superplasticizer of PCE (Normet type Tamcem 21 RA).

2.2 Concrete mix design

The local materials were used for concrete mix design and they have been reported previously by Jonbi et al., [8,9]. Table 1 shows the concrete mix design of four different PCE composition.

Table 1. Concrete mix design with *f*'c 50 MPa

Material	Unit	BK0	BK1	BK2	BK3
OPC	kg/m^3	484,12	484,12	484,12	484,12
Fine aggregate	kg/m^3	793,12	793,12	793,12	793,12
Coarse aggregate	kg/m^3	971,04	971,04	971,04	971,04
Water	kg/m^3	193,65	193,65	193,65	193,65
PCE	l/m^3	0	2,42	4,84	9,68

The addition of PCE was classified by a nomenclature that BK0 is the concrete's mix that designed for the addition of 0% PCE, BK1 for the addition of 0.5% PCE, BK2 for the addition of 1% PCE and BK3 for the addition of 2% PCE, as shown in Table 2.

Table 2. Nomenclature and number of compressive strength test

Code	PCE	Age of concrete (d)				Number of Sample
		3	7	14	28	
BK0	0%	3	3	3	3	12
BK1	0.5%	3	3	3	3	12
BK2	1%	3	3	3	3	12
BK3	2%	3	3	3	3	12

2.3 Measurements of slump retention and compressive strength

Figure 1 shows the test of slump retention for the verification of decreasing slump flow according to the standard ASTM C 143-90. The measurements of slump retention were carried out at 0, 15, 30, 45, 60 and 75 minutes.

Fig. 1. Testing of slump retention

This study used a cylindrical tube of having dimensions of 150 mm external diameter and 300 mm high to follow the standard ASTM 39. Figure 2 shows the measurement equipment testing of compressive strength. Compressive strength of the HPC samples was performed at 3, 7, 14 and 28 d of the concrete's age.

Fig. 2. Testing of compressive strength

Correlation between the slump retention and the compressive strength for the HPC sample was verified using the results of testing the slump retention at 0, 15, and 30 minute and testing the compressive strength at 7 and 28 day.

3 Results and discussion

3.1 Slump retention

The results of slump retention for mixture of concrete with the variables of adding PCE by 0%, 0.5%, 1% and 2% and mixing time by 15, 30, 45, 60 and 75 minutes can be analysed to get better understanding of the workability of HPC. Figure 3 shows that the workability of HPC is still able to be used in construction industry since the slump retention behavior of concrete with a composition of 2% PCE can be maintained until 45 mn with a slump value of 10 cm. Meaning that the proper amount of added PCE would be effective in improving the slump retention due to the addition of PCE can induce greater physico-chemical surface interactions through electrostatic interactions [10-12].

Empirical evidence shows that the addition of PCE in a mixture of concrete may improve the workability of HPC. The HPC performance of improved by the addition of PCE by 15% and 20% can reach at 45 mn of slump retention capability. This study verified that the synthesis of designed HPC by adding 2% of PCE superplasticizer can have an optimal slump retention capability of 45 mn, and then after 45 mn the compressive strength slowly continues to decrease [7, 13].

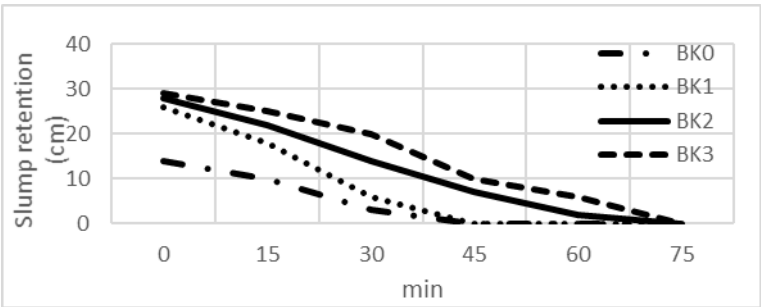

Fig. 3. Results of testing the slump retention

3.2 Compressive strength

Figure 4 shows that the increasing of PCE added into a concrete slurry can increase the compressive strength of HPC to get verified at concrete's age of 3 d. The figure shows the increase in compressive strength from 25.62 to 30.26 to 31.93 to 34.22 MPa because of the addition of PCE into the mix of concrete increases from 0% to 0.5% to 1% and to 2%, respectively. The increase of compressive strength can also be verified at the ages of 7, 14 and 28 d. The compressive strength has never reached at its planned compressive strength of f'c 45 even at age of 28 d due to the addition of PCE by 0%. It can reach at its planned compressive strength of f'c 45 at age of 28 d by the addition of PCE by 0.5%. By adding 1% of PCE into concrete slurry, the compressive strength reaches at 47.87 MPa, which is 2.42 MPa higher than its planned compressive strength of f'c 45, at age of 14 d and 49.81 MPa, which is 4.36 MPa higher than its planned compressive strength of f'c 45, at age of 28 d. Finally, by adding 2% of PCE into a mixture of concrete, the compressive strength can reach at 50.81 MPa, which is 2.94 MPa higher than the compressive strength of HPC of

added 1% of PCE, at age of 14 d and 53.84 MPa, which is 4.03 MPa higher than the compressive strength of HPC of added 1% of PCE, at age of 28 d.

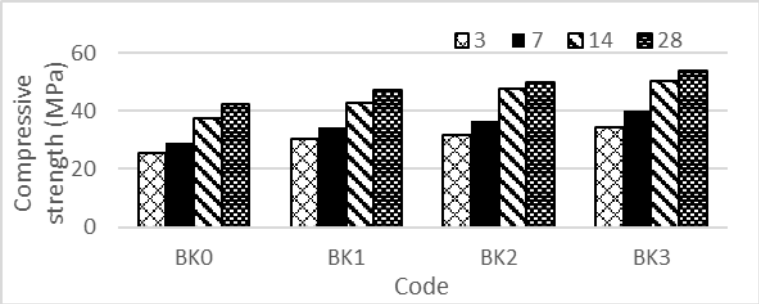

Fig. 4. Results of testing the compressive strength.

The results (Table 3) of testing at age of 28 d with the variable of PCE added by 0%, 0.5%, 1% and 2% have the compressive strengths of 42.47, 47.05, 49.81, and 53.84 MPa, respectively. The maximum value of compressive strength was verified to reach at 53.84 MPa the workability of HPC of added 2% PCE with an increase in compressive strength of 26.77% compared to that of added 0.5% PCE. Empirical evidence verified that the addition of superplasticizer into a mixture of concrete can increase workability of the HPC due to the presence of PCE nanoparticles in concrete slurry fills the cavities of concrete and thus can result in strengthening of bonds among the concrete materials the [14-16].

Table 3. Results of increasing the compressive strength

Addition of PCE (%)	Compressive strength (MPa)	Increase of compressive strength
0	42.47	0%
0.5	47.05	10.80%
1	49.81	17.29%
2	53.84	26.77%

3.3 Relation between slump retention and compressive strength

The results (Fig. 5) of plotting a correlation between the slump retention and the compressive strength reveals that the decreasing of slump retention does not make a significant decrease in compressive strength of the HPC. The compressive strengths of testing at 0, 15 and 30 mn have not clearly affect the value of slump retention at the performance of HPC measured at the ages of 7 and 28 day.

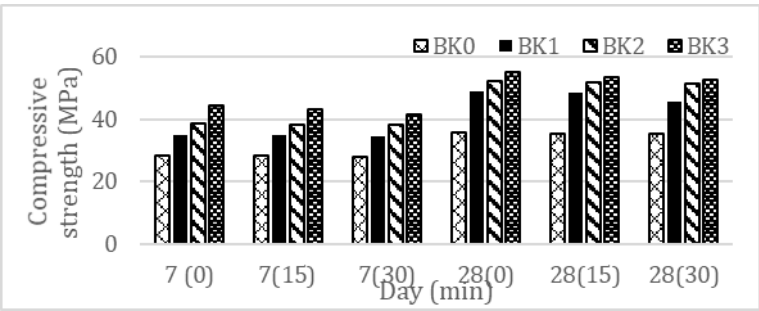

Fig. 5. Correlation between the slump retention and the compressive strength

4 Conclusions

This study used four different concrete mix designs of HPC with the variable of added 0%, 0.5%, 1% and 2% of the PCE to verify the slump retention capabilities and compressive strengths. By analysing the results of slump retention and compressive strength can conclude that:

1. The optimal slump retention of 45 mn with its value of 10 cm can be achieved by adding 2% of PCE.
2. A very high compressive strength of 53.84 MPa for HPC can be achieved by adding 2% of PCE, thre is an increase in the compressive strength of 26.77% compared to the control sample of HPC without addition of PCE.
3. Slump retention does not affect the compressive strength of HPC.

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