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Optimizing polycarboxylate based superplasticizer dosage with different cement type

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Abstract

The use of polycarboxylate ether (PCE) as superplasticizer (SP) in the manufacture of high strength concrete is increasingly common. Each brand of SP available on the market has different compositions, causing differences in dosage requirement and the resulting characteristics. Beside SP type, cement type and composition also affect the fresh and hardened concrete properties. In this study, the optimum dosages of several brands of PCE superplasticizer in making mortar were investigated. Two different cement types were used. The effect of SP on flowability, setting time, and resulting compressive strength were evaluated. The results show that with the increase of SP dosage in mortar mixture, the flowability increased. However, there is an optimum value for each brand and for each water cement ratio. The increase of flowability is accompanied by an increase in compressive strength until it reaches the optimum level. Nevertheless, excessive use of SP could lead to bleeding and segregation, and reduce the compressive strength. It was found that ordinary Portland cement (OPC) requires higher SP dosage than Portland Pozzolan cement (PPC) for the same flowability. Longer setting time was observed for all mixtures employing SP, at different degrees of extension. It correlates with the slump retention time. Simple method to determine the optimum dosage is suggested in this paper.

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Keywords: polycarboxylate; superplasticizer; setting time; dosage; cement type; OPC; PPC.

1. Introduction

High strength concrete essentially need to use superplasticizer to reduce cement interparticle force and to disperse the particle evenly in the concrete mix. High compressive strength could only be achieved when low water to

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cement ratio (w/c) is ensured in the concrete mix design, while maintaining adequate workability of the fresh mixture. Superplasticizer addition reduces the cohesiveness of the cement particles by electrostatic repulsion, in the case of naphthalene or melamine-based superplasticizer; and by a combination of electrostatic and steric repulsion mechanism in the case of polycarboxylate based superplasticizer [1,2].

Different brand of polycarboxylate ether (PCE) superplasticizer has different molecular structures, affected by the manufacturing process. Its chemical structures consist of main chain and side chains with different length and density, and will have different effectivity in increasing the workability of concrete mixture [3]. Several researches have been done on the dispersion mechanism based on the molecular structures of the materials, showing that it could cause changes in the dispersion behavior (slump flow), performance on slump retention (slump loss), delay on the reaction rate (setting time) and the particle packing improvement (compressive strength) with different chemical structures [4-8].

The effect of superplasticizer in concrete fresh mixture depends on its dosage and distribution in the mixture. Very low dosage will not affect the rheological behavior of the fresh mixture, and on the other hand very high dosage may cause detrimental effect such as bleeding and segregation. Yamada et al. [9] remark that there are critical dosage and saturation dosage of SP in the concrete mixture. Critical dosage is defined as minimal dosage needed to cause overall effect of SP in the mixture. Below critical dosage, the mixture will behave as if no SP is added. Saturation dosage implies that further addition of SP will not lead to improvement of rheology behavior of the concrete mixture. However, the SP dosage must also have an upper limit value, as higher dosage reduces cohesion of the mixture due to excessive bleed water, lowers the viscosity of the cement paste, and hence induces segregation. Interaction of SP in the concrete mixture is a complex process, as it has to compete with the dissolution of cement compound. Dissolution of sulfate ions from gypsum to control the setting time of cement occurs at the beginning of the process. The presence of gypsum, as well as other compounds, affects the effectivity of SP [9]. Direct addition of SP into mixing water may cause different SP dosage requirement compared to delayed addition. Lower SP dosage requirement was observed for delayed addition, however, delayed SP addition is not always possible when considering the mixing equipments and production cycle.

Different cement types may alter the critical dan saturation SP dosages, because of the differences of the chemical compositions of cement. Variation of chemical composition and physical properties of one brand of cement between shipments may occur, and thus the optimum SP dosage needs to be adjusted for a good and consistent result. The addition of supplementary cementitious material can also reduce or increase the SP dosage requirement. Adding fly ash tends to reduce the SP dosage required to achieve the same workability, because of its chemical and physical properties [10].

The PCE-based SPs currently available in the market in Indonesia, are supplied by several manufacturers, both local and international, competing one to each other. Each brand of PCE-based SP comes with different behavior and characteristics, aside from the availability and price range. The customization of the SP by adding other ingredient, such as retarder, accelerator, foam buster, causes further confusion on the dosage requirement of the SP to produce a good, homogeneous and predictable fresh concrete. The objectives of this research are to study the different characteristics of polycarboxylate-based (PCE) superplasticizer commonly available in the market and to evaluate the proposed simple testing method to determine its properties. Simple testing method is proposed to simplify the optimization process. Two cement types were used to show the influence of cementitious mixture on the optimum dosage needed.

2. Experimental methods

2.1. Materials and mixtures

Five brands of PCE-based SP that currently available in the local market in Indonesia, produced by four different manufactures, were used in this study. The coding for the SPs used are (a) CC, (b) SV, and (c) AS, produced by three different producers; (d) BA and (e) BS produced by the same producer. Two cement types, i.e. Ordinary Portland cement (OPC) and Portland Pozzolan cement (PPC) from two different cement producers were used in this research.