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The evaluation of concrete properties including zeolite and micro-nano bubble water in the chloride curing condition

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ABSTRACT: The highest part of chemical ions present in the seawater is related to the chloride ion. In this research, the effect of chloride curing condition on the properties of concrete including zeolite as a mineral admixture and micro-nano bubble water is evaluated. Based on the experiments including X-ray diffraction, compressive strength, water absorption, chloride permeability and electrical resistance, it was determined that the addition of zeolite and micro-nano bubble water to the mixture improved the properties of concrete in the chloride conditions. Also results showed that the chloride curing condition causes an improvement in the properties of concrete at the age of 28 days due to the formation of Friedel salt. With increase in age of concrete up to 90 days and decomposition of Friedel salt composition in mixtures, the process of improvement is reduced. The highest effects on improving the mechanical properties and durability of concrete at the age of 28 days is related to the mixture including 15% zeolite and 100% micro-nano bubble water under chloride curing conditions. Improvement contents in the mentioned situation are 47, 78, 254, 84 and 49 percent corresponds to the compressive strength, tensile strength, electrical resistance, chloride permeability and water absorption test respectively.

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1. Introduction

It is verified from the studies that the pozzolanic materials reduce the ingress of chloride by enhancing the microstructure condition and chloride binding behavior [1-4]. Recently using natural zeolite as a mineral admixture in concrete is increasing [6, 7]. Natural zeolite is including large amount of SiO2 and Al2O3 [8, 9]. Recently nanotechnology industry entrance into the construction presents a numerous of opportunities and challenges. Micro-nano bubbles (MNBs) are small sized bubbles with the diameters on the order of micro and nano meters, showing major potential in environmental remediation. Results showed that micro-nano bubbles could effectively enhance the mechanical properties of the concrete but reducing its workability. It was known that compressive and tensile strength increased for 16 and 19% respectively [10-13].

2. Experimental Program

A locally ordinary Portland cement type I was used in this study. Also the zeolite was used as a cement replacement material. Micro-nano bubble water have been served as a substitute with mixing concrete water. River sand was also applied as fine aggregate with a specific gravity of 2620 kg/m3 and crushed limestone as the coarse aggregate with a maximum size of 19 mm and specific gravity of 2680 kg/m3 and a polycarboxylic super-plasticizer with a density of 1.08 g/cm3 and a pH of 7 used in this research. In order to evaluate the mechanical and durability properties of concrete, mixture proportions were made in two phases. The first phase has 5 mixtures including ratios of 10 and 15% zeolite instead of cement and 50 and 100% of the micro-nano bubble water instead of the concrete water. The second phase consists of 4 mixture ratios in the form of combinations of 50 and 100% micro-nano bubble water with 10 and 15% zeolite. In all mixtures, the water to cement ratio was 0.45.

In this research, in order to study the mechanical properties and durability of mixtures including zeolite and micro-nano bubble water in chloride curing conditions and its comparison with standard conditions, two treatment conditions were used. The compressive strength, water absorption, rapid chloride permeability and X-Ray diffraction (XRD) and electrical resistance test were done.

3. Results and Discussion

The XRD test results for mixtures under two treatment conditions (standard and chloride at the age of 28 and 90 days have been illustrated in Figure 1. The results showed that the addition of zeolite to concrete under chloride curing conditions results in the formation of Friedel's salt ($Ca_2Al(OH)_6Cl \cdot 2H_2O$) in concrete, but over 90 days, producing of stratlingite (C_2ASH_8) causes salt to decomposition of Friedel's salt [14]. The content of Friedel's salt in the mixture including 10% zeolite, 15% zeolite and 100% nano-bubble is more than the reference mixture. Therefore, Friedel's salt has been produced in these mixtures more than in the control mixture under chloride treatment conditions.

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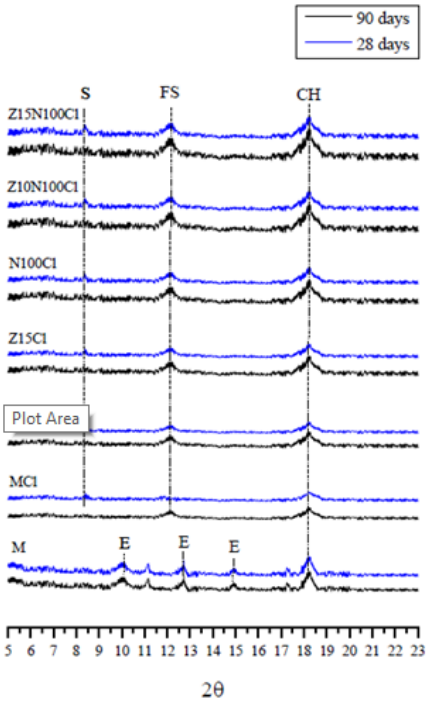
Figure 1. XRD analysis of mixtures (S: Stratlingite, E: Ettringite , FS: Friedel's salt)



The results of mixtures compressive strength showed that the mixture including zeolite shows higher compressive strength compared to the control mixture at the age of 28 and 90 days under standard condition. By adding the percentage of pozzolan from 10 to 15%, the amount of strength is increased. This can be attributed to pozzolanic activity and the improvement of the hydration process in the mixtures contains zeolite. Increasing compressive strength of mixtures with zeolite under chloride curing conditions can be attributed to the production of Friedel's salt in these mixtures [15, 16]. With the increasing age of mixture, the Friedel's salt is decomposed and the compressive strength of the mixture is also reduced under chloride curing conditions. It is in accordant with the XRD result that is discussed before.

The minimum water absorption is belonging to the mixture including zeolite with the value of 1.7% for water absorption of 30 minutes at the age of 28 days.

The rapid chloride permeability test results of mixtures treated under standard curing and chloride curing conditions showed that the chloride ion enters into the mixture under treated chloride conditions is less than those mixtures treated under standard. In the control mixture at the age of 28 days, less chloride ions permeated into the MCl mixture compared to the M mixture, but at the age of 90 days, the chloride ions permeability rate in the M mixture was less than the MCl mixture by 2%.

In mixtures treated in chloride conditions, the electrical resistance has progressed more than other mixtures in standard conditions. The maximum electrical resistance in chloride mixtures is related to the N15Z100Cl mixture, which has improved by 35% compared to the mixture N15Z100, 254% compared to the control concrete under the standard conditions (M) and 234% compared to the chloride conditions (MCl).

4. Conclusions

The main results of this work can be drawn as follows:

1. Zeolite and micro-nano-bubble in standard curing condition improved mechanical and durability properties of concrete based on the experiments conducted in this study such as XRD, compressive strength, electrical resistance, water absorption, chloride permeability. The mixture including 15% zeolite and 100% micro-nano bubble water causes the best improvement among the treated mixture under standard curing conditions.

2. Producing of Friedel's salt as a chloride compound was observed in all mixtures under the chloride curing conditions by X-ray diffraction test.

3. With the increasing of concrete mixture age, the Friedel's salt is decomposed and the compressive strength of the mixture is also reduced under chloride conditions. It is verified and in accordant with the XRD images in this study.

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