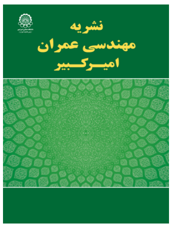

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Effect of recycled materials on autogenous shrinkage of ultra-high performance concrete

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ABSTRACT: The study aims is to decrease the silica fume (SF) content of UHPC by using natural zeolite (NZ) with different levels of replacement (25%, 50%, 75%, and 100% by volume), to mitigate autogenous shrinkage with almost equivalent mechanical performance. The results demonstrated that the addition of NZ as a replacement of SF had a positive effect on maintaining internal RH in the higher range as well as in reducing the autogenous shrinkage of UHPC. The mixtures with 25%, 50%, 75%, and 100% replacing SF by NZ had lower autogenous shrinkage compared to reference mixtures containing 100% SF. The results of Thermogravimetric and microstructure analysis indicated that NZ had appropriate pozzolanic activity. The results of the compressive strength test showed that by replacing 50% SF with NZ, the 90 days compressive strength of 164.37 MPa could be achieved, which was only slightly lower than the reference mixture with 90 days compressive strength of 169.07 MPa. replacing SF with NZ yielding a cost-effective solution. By replacing 50% NZ replacement of SF, UHPC mix with 90 days compressive strength over 150 MPa, with low autogenous shrinkage and relatively low cost can be produced.

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1. Introduction

Ultra-high performance concrete (UHPC) is advanced concrete with excellent mechanical and durability properties[1,2]. Despite the high cost of UHPC production compared to conventional concrete, it is competitive, because of the reducing or eliminating of reinforcements in structural elements, Reducing the thickness and weight of concrete members, increasing service life, and reducing repair and maintenance costs [3]. Furthermore, UHPC has a the potential for Retrofitting concrete structures [4]. To produce UHPC, the use of aggregate and pozzolans with fine grain size is required [5]. Various types of fine size powders have been used as pozzolan and filler in concrete mixtures to achieve high mechanical and durability properties [6–9]. Due to its superior properties, such as high pozzolanic activity, enhancement of rheological characteristics, and it's filling ability, silica fume (SF) is the principal constituent of UHPC mixtures [10,11]. The SF contents of UHPC mixtures are generally 10–30% of the cement mass [11,12].

This study by replacing SF with NZ, aimed at producing UHPC with low autogenous shrinkage and low cost with appropriate mechanical performance.

2. Experimental

2.1. Material properties

In this study, Type II portland cement in accordance with ASTM C150 with a specific gravity of 3.19 and a fineness of 3500 was used. Fig. 1 shows the particle size distribution (PSD) for cement, NZ, SF, and QS used in the UHPC. Fig. 2 provides the SEM micrograph and XRD analysis for NZ. According to the figure, prismatic clinoptilolite crystals of NZ were observed. The XRD analysis from Fig. 2 shows that clinoptilolite is the major crystalline phase of NZ and indicates that it was crystallized. The clinoptilolite content of the NZ was estimated at 79.17%.

2.2. Mix-design optimization and mixture proportions

Proportioning of UHPC mixtures is based on particle packing density.. Mix proportions and packing density of UHPC mixtures are given in Table 1.

3. Results and discussion

The TG and DTG curves of pastes indicated that SF-CP and NZ-CP consumed a significantly higher amount of CH than CP that confirm the pozzolanic activity of SF and NZ.

To study the microstructure of UHPC mixtures, scanning electron microscope (SEM) and energy dispersive spectroscopy (EDS) were used. It can be seen that 0NZ/100SF mix has fewer capillary pores and the denser matrix of C–S–H, compared to the 100NZ/0SF mix.

The mixture containing 100% SF (0NZ/100SF), showed the best results of compressive strength. The pozzolanic activity of SF is higher than that of NZ, so in samples containing greater SF, the rise in compressive strength comes earlier.

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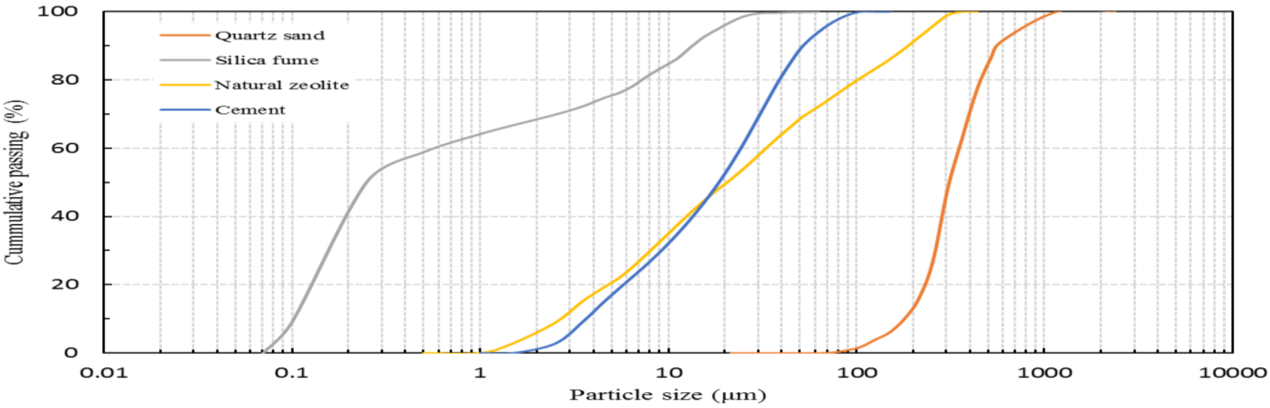

Fig. 1. PSD of granular materials

Table 1 Concrete mix proportions (kg/m^3)

Mixture	0NZ /100SF (Reference)	25NZ /75SF	50NZ /50SF	75NZ /25SF	100NZ /0SF
Cement	896	896	896	896	896
Quartz sand	1019	1019	1019	1019	1019
Silica fume	268	201	134	67	-
Natural zeolite	-	67.3	134.6	201.9	269.2
Water	186.2	186.2	186.2	186.2	186.2
Superplasticizer	20.1	20.1	20.1	20.1	20.1
Packing density	0.7807	0.7698	0.7550	0.7489	0.7389

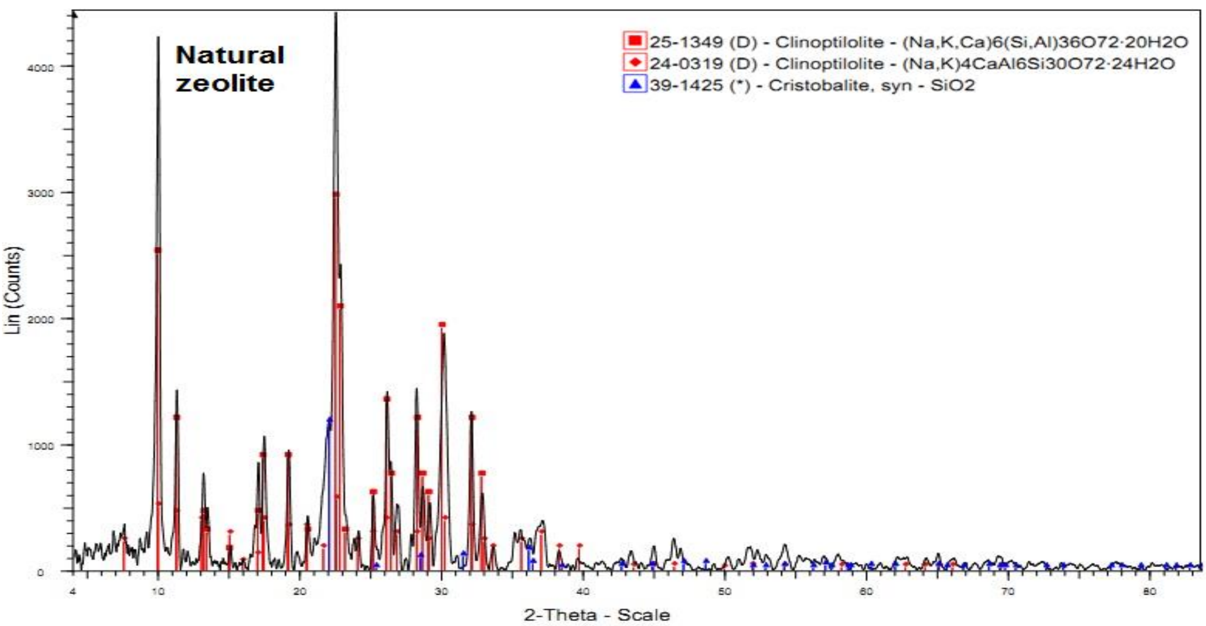

Fig. 2. XRD analysis of natural zeolite

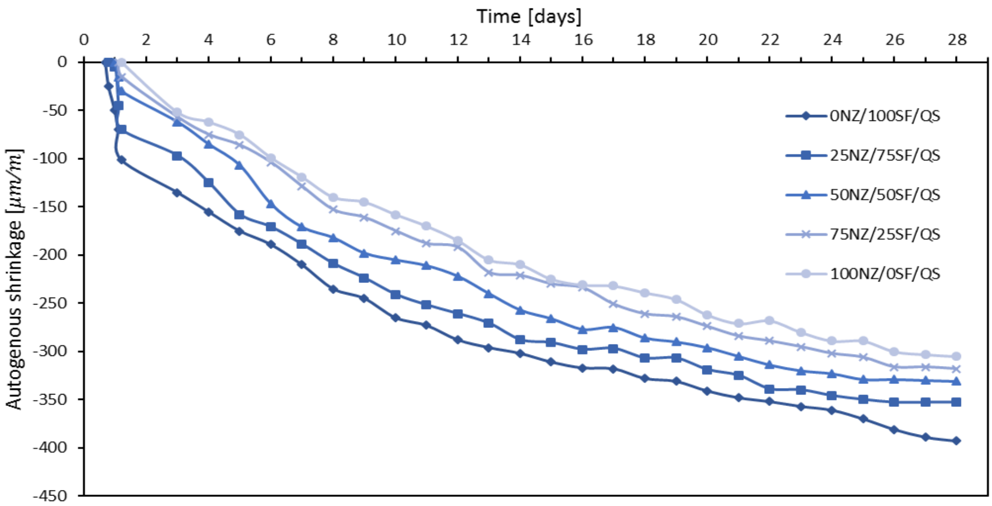

Fig. 3. Autogenous shrinkage of specimens

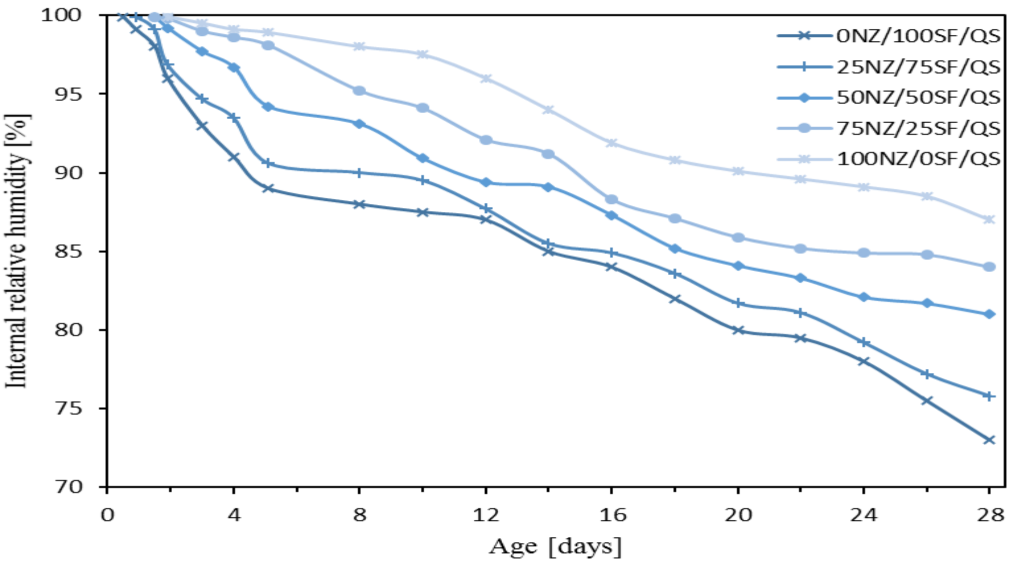

Fig. 4. Internal RH of specimens

The measured autogenous shrinkage for all samples is shown in Fig. 3 From the the results, reference mix containing 100% silica fume exhibits a significant amount of autogenous shrinkage.

The results indicate that the addition of NZ as an alternative to SF has a positive effect on maintaining internal RH at a high range and increasing the internal RH content of NZ-containing specimens has led to a decrease in autogenous shrinkage Fig. 4.

4. Conclusion

The results of TGA and microstructure analysis indicated that NZ had a high pozzolanic activity but less than SF. The compressive strength of the UHPC mixtures with NZ was also slightly less than that of mixtures with SF with a similar replacement.

Adding NZ as a substitute for SF had a positive effect on maintaining internal RH in the higher range as well as in reducing the autogenous shrinkage of UHPC. The internal RH of the mixture with 100% NZ (100NZ/0SF), showed 13.8% higher than the mixture with 100% SF (0NZ/100SF) at 28 days after mixing. Also, the UHPC mixtures with 25%, 50%, 75%, and 100% NZ replacement, had lower autogenous shrinkage compared to mixtures containing 100% SF.

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